Solving Three Major Biases of the ETAS Model

to Improve Forecasts of the 2019 Ridgecrest Sequence

Christian Grimm,
Department of Statistics, Ludwig-Maximilians-University Munich

26.05.2022

Epidemic Type Aftershock Sequence (ETAS) Model [1, 4, 3]

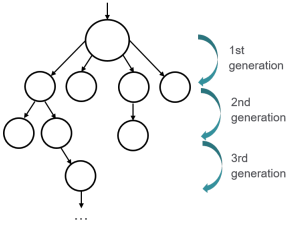


Figure: Branching Model Structure

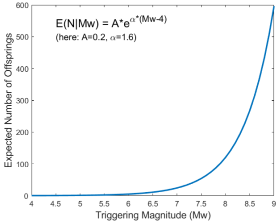


Figure: Expected Aftershock Productivity

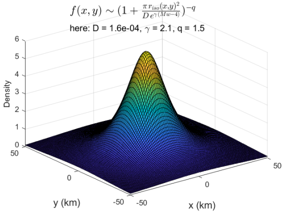


Figure: Spatial Decay of Aftershock Rates

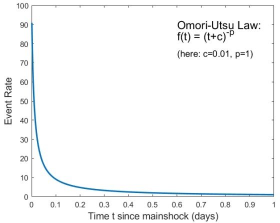


Figure: Temporal Decay of Aftershock Rates

Bias 1: Isotropic Spatial Kernel?

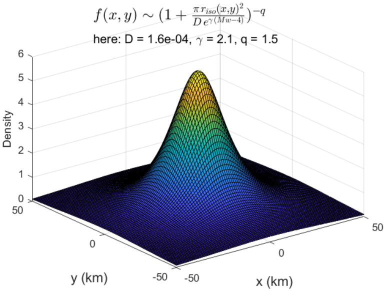


Figure: Infinite Isotropic Spatial Kernel

?

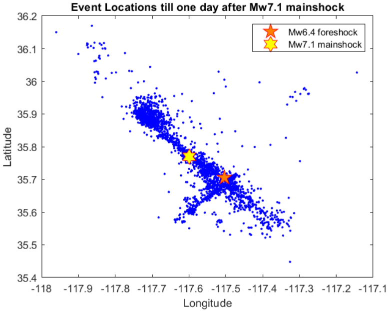


Figure: 2019 Ridgecrest Aftershock Locations

- ✎ *Aftershocks occur along typically elongate rupture planes* [2]
- ✎ *As a consequence of this bias, events at the endpoints of the mainshock rupture may not be identified as direct aftershocks*

Bias 2: Infinite Spatial Kernel?

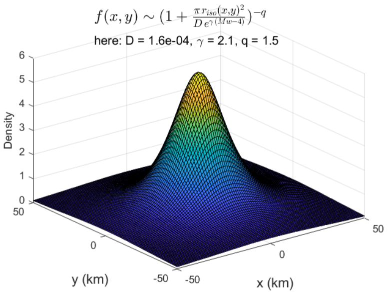


Figure: Infinite Isotropic Spatial Kernel

?

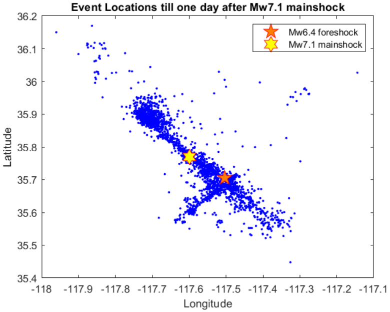


Figure: 2019 Ridgecrest Aftershock Locations

- *Aftershocks occur in a locally restricted area around the mainshock*
- *As a consequence of this bias, the aftershock productivity of small events is overestimated at the cost of large earthquakes*

Bias 3: Short-Term Aftershock Incompleteness

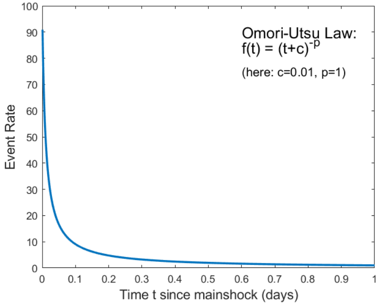


Figure: Power Law Decay of Aftershock Rates

?

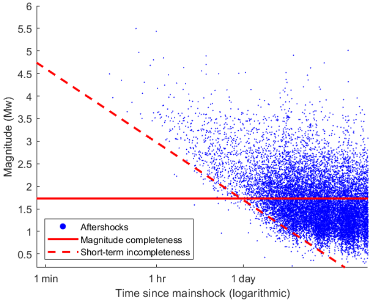
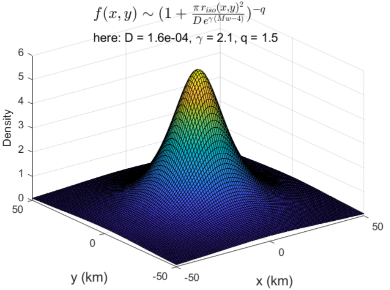


Figure: Short-Term Aftershock Incompleteness

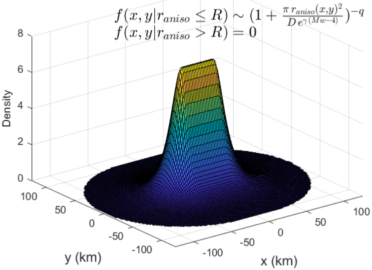
- ✎ *Overlapping coda waves hinder records of early aftershocks*
- ✎ *As a consequence of this bias, the Omori-Utsu law is misfitted and the aftershock productivity of strong earthquakes underestimated*

Solving Three Biases at Once

1) A generalized, anisotropic and locally restricted spatial kernel



$\Rightarrow$



2) Incorporate rate-dependent short-term aftershock incompleteness into the ETAS intensity function

Forecasting the 2019 Ridgecrest Sequence

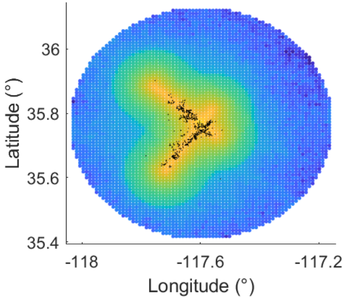


Figure: Spatial Forecast of Aftershocks of M6.4 Foreshock

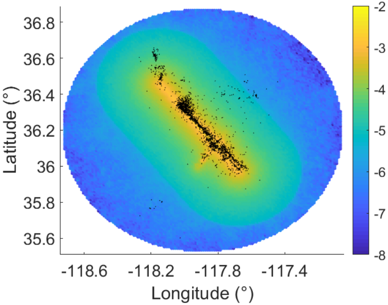


Figure: Spatial Forecast of Aftershocks of M7.1 Mainshock

✎ *The anisotropic kernel provides very good forecasts of the aftershock clouds of both Ridgecrest events*

Forecasting the 2019 Ridgecrest Sequence

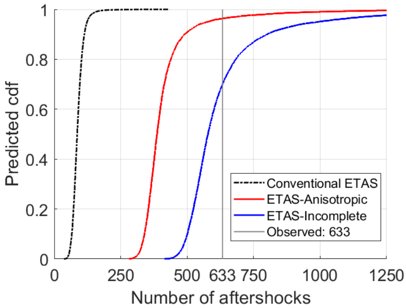


Figure: 10,000 Forecasts of the Number of Aftershocks Triggered by the M6.4 Foreshock

- ✎ *The conventional ETAS model provides an unacceptable forecast of the aftershock count*
- ✎ *Only the ETAS-Incomplete model provides a realistic forecast of the cluster size*

Thank you very much...

... I am happy to discuss your feedback and questions :)

Further Information

Email: Christian.Grimm@stat.uni-muenchen.de

Matlab Source Code Available at:
https://github.com/ChrGrimm/ETASanisotropic

Publication:
Grimm, C., Hainzl, S., Käser, M., Küchenhoff, H., 2022. Solving three major biases of the ETAS model to improve forecasts of the 2019 Ridgecrest sequence. *Stochastic Environmental Research and Risk Assessment*

References I

[1] Abdollah Jalilian. ETAS: An R package for fitting the space-time ETAS model to earthquake data. *Journal of Statistical Software*, 88(1), 2019.

[2] David Marsan and Olivier Lengliné. Extending earthquakes' reach through cascading. *Science*, 319(5866):1076–1079, 2008.

[3] Yosihiko Ogata. Space-time point-process models for earthquake occurrences. *Annals of the Institute of Statistical Mathematics*, 50(2):379–402, 1998.

[4] J. Zhuang, Y. Ogata, and D. Vere-Jones. Stochastic declustering of space-time earthquake occurrences. *Journal of the American Statistical Association*, 97(458):369–380, 2002.