

KEM Research Question

KEM-36 Continuation of KEM-04 to adapt to latest versions (V6/V7) GMM

Objective

In 2019 the KEM-04 project has successfully executed 3D seismic modelling to better understand characteristics of induced earthquakes of the Groningen gas field and the propagation of seismic waves and their effects on seismic structural response in the Groningen area (<https://kemprogramma.nl/blog/view/37cfcc1c-c6fd-4b38-a173-32b8f8467933/kem-04-data-driven-study-on-seismic-structural-features-of-groningen-ground-motions-finished>).

The results of KEM-04 have given suggestions to evaluate the Ground Motion Model (GMM) V5 and to possibly improve subsequent ground motion models. As ground motion model V7 is now available and the results of KEM-04 refer to ground motion model V5, the question arises whether the identified issues in V5 still apply to the latest ground motion model.

The output of the project will be used to evaluate the Ground Motion Prediction Model V7 of NAM, which has been built into the TNO risk model for Groningen, and for other earthquake-engineering-related uses, for example, to derive relevant time-histories for structural assessment or to assess the effect of larger magnitudes for which recorded data are absent or scarce, yet drive the risk figures in the Groningen area.

State of the art, background

Many questions or comments, coming from the Dutch Ministry of Economic Affairs and Climate and State Supervision of Mines and Groningen NCG knowledge platform meetings and NPR, refer to "horizontal and vertical seismic signatures". The main concerns raised are:

- a) the overall validity of the risk assessment model;
- b) accurate prediction of the (strong) effects of shallow and deep subsurface over the Groningen area, including also their spatial heterogeneity; and
- c) the determination of 3D seismic input for evaluating the fragility functions used in the seismic risk assessment from NAM.

In KEM-04 issues were identified with the V5 GMM model (although these are only indirectly related to the a-c questions above). These issues may or may not have been resolved in the GMM V7 model. This follow-up project will revisit KEM-04 with the results of the new GMM V7 model. This GMM V7 has been built into the TNO risk assessment model for Groningen. TNO implementation team expressed some concerns, which have been reported and should be taken into account in developing this project. An independent review of GMM V7 on behalf of SodM will be finalised, report will be available in Q1 2023, and it should also be considered as background of this project.

Finally, in June 2022 a Mmax workshop was held. Insights obtained on induced seismicity and effects of larger magnitude earthquakes are useful for this research question.

Research Questions

The research questions posed here were answered in KEM-04 for the Groningen Ground Motion Model (GMM) V5: *Has the GMM V7 solved the issues found for GMM V5?*

Phase 1 has addressed research question 1 and parts of research question 3 and was used to revisit the results of KEM-04 without conducting new 3D simulations.

Phase 2 will address the original research question 2 and the remaining part of research question 3. Additionally a research question was added on request of SodM (research question 4).

Research Question 1: Analysis and implementation of Groningen Ground Motion Model V7 and comparison with V5.

- Implement and evaluate the Groningen GMM V7. Compare measurements with predictions of GMM V7. How well does the new model perform compared to GMM V5 and – more in general – with the data now available for the investigated region?

Research question 2: To what degree do the results of KEM-04 RQ2 change or not when comparing the KEM-04 3D seismic modelling results with 3D seismic modelling referring to the V7 ground motion model (Zechstein Salt and near surface heterogeneity to be modelled the same as in KEM04). This research question is divided in three topics:

1. Investigation of non-linear effects on ground motion in Groningen
2. Update of 3D physics-based SPEED simulations considering elongated rupture models
3. Assessment of the period-to-period (p2p) correlation

These topics are consistent with the original research question 2:

- Compare and explain the different values considered for some model components regarding the source (stress-drop, source geometry and associated directivity effects) or the propagation (frequency-dependence of damping), and how it may impact the final ground motion model.
- Analyse the consistency between the extended source models considered in GMMV7 and those highlighted during the Spring 2022 Mmax workshop.
- Investigate whether the 3D simulations performed in KEM04 could help in answering the period-to-period correlation (at least at long periods where the simulations are deterministic) issues raised with the implementation of GMM V7.
- Update KEM04 non-linear computations and compare with GMMV7 ones (motivation: one of the key conclusion of KEM04 was that GMMV5 was overestimating Non Linear effects. The fact that GMMV7 is underestimating observed PGA and high frequencies suggest that this overestimation may still be an issue).
- Redo previous analyses and analyse potential larger magnitude hazards.
- Additional questions to be considered:
 - Are the stress-drop values obtained in these projects consistent with the "stress-parameter" values used in GMM-V7 stochastic models for induced events and stress-drop values considered for larger European magnitude tectonic events in recent publications (e.g. Bindi and Kotha, 2020; Bora et al., 2017; Edwards and Fäh, 2013)?
 - How do the shallow damping values considered in GMM-V7 compare with the frequency-dependent quality factor proposed in Paolucci et al (2020)?
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Research question 3: Improving ground motion predictions.

- Based on result of questions 1 and 2, and the ground motion model V7 review the earlier recommendations of KEM-04-RQ3 and indicate whether the recommendations on possible future improvements and data requirements change.

Research question 4

Formulate and apply a correction for the underestimation of PGA and consider the methods proposed by the reviewers of the GMM V7 model for SodM.

Deliverables expected

- Report detailing the results of topics 1, 2 and 3 within RQ2 and RQ3. Separate report and programming for RQ4. The reports should be readable without specific knowledge of the earlier reports on KEM-04. The report and programming for RQ4 should enable other parties to implement correction factors to the GMM V7 model. If necessary an implementation guideline could be written.
- Presentations to the KEM panel at (22th or 23th) November 2023 and in June 2024.

Timeline

The final finished product will be delivered by 31 may 2024.

Expected use

The research results will be used to:

- communicate to the Groningen platforms;
- steer the developments of the public Groningen seismic hazard and risk assessment (public SHRA) built by TNO;
- make a correction to the GMM V7 for the underestimation of PGA.
- provide guidance for the use of GMM V7 to the broader research and engineering community, beyond the public risk assessment.
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Expertise and tools preferred for the team

Knowledge and experience with the research questions and answers of the KEM-04 project. As such only the KEM-04 team can perform this project in an time efficient and constructive manner, consistent with the KEM-04 project execution and reporting. Preferably the TNO people involved in the building of the public Groningen SHRA would be involved in the KEM-36 as well, in particular to speed up implementation of GMM V7 model.

Quality assurance, Organisational and communication requirements

- Regular project meetings between project team and MEAC/SodM, TNO and members of the KEM-subpanel for model development. Additionally, it is also strongly recommended to involve Pauline Kruiver (KNMI, formerly with Deltares) in the project.
- Quality assurance team as part of the project, including scientific experts.

References

- Publications on the NAM model by Bommer, Kruijver, Bozorgnia, etc.
- NAM reports in seismic risk model outcomes, NAM portal.
- NJG special issue.
- TNO reports (www.nlog.nl) including the reporting on GMM V7 implementation
- KEM-04 reports.
- NAM GMM V7 report, Mmax workshop information (<https://www.nam.nl/over-nam/onderzoeksrapporten.html>).
- Reporting on independent review of GMM V7 on behalf of SodM.