Intensity Prediction Equation for Austria: Applications and Analysis

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Contents

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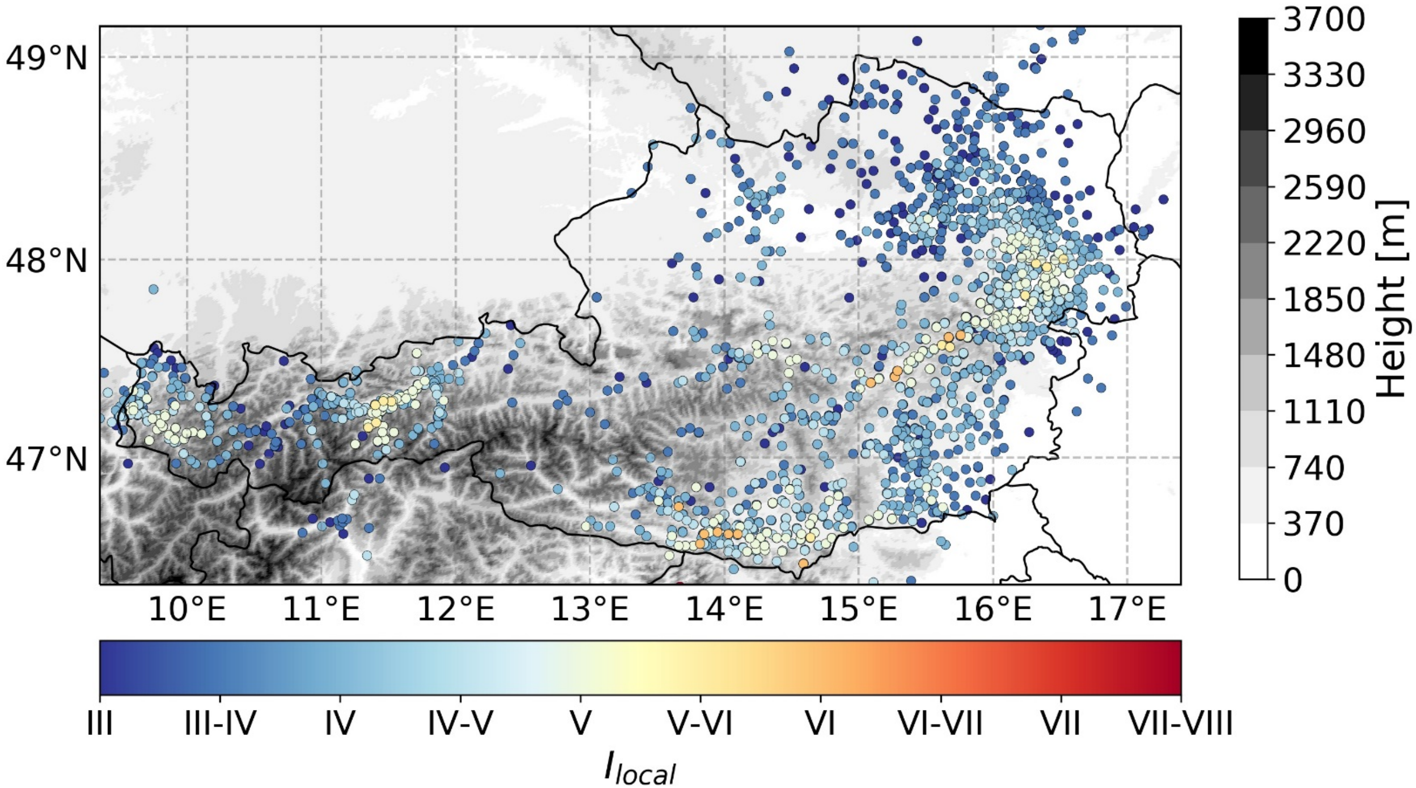
1. Macroseismic data set

Austrian Earthquake Catalog (period 2004-2018)

- 42 earthquakes with $3.0 \leq M_w \leq 5.4$ and 3,214 IDP's



- Intensities >= III were considered
- At least 10 IDP's.

2. Intensity Prediction Equation (IPE)

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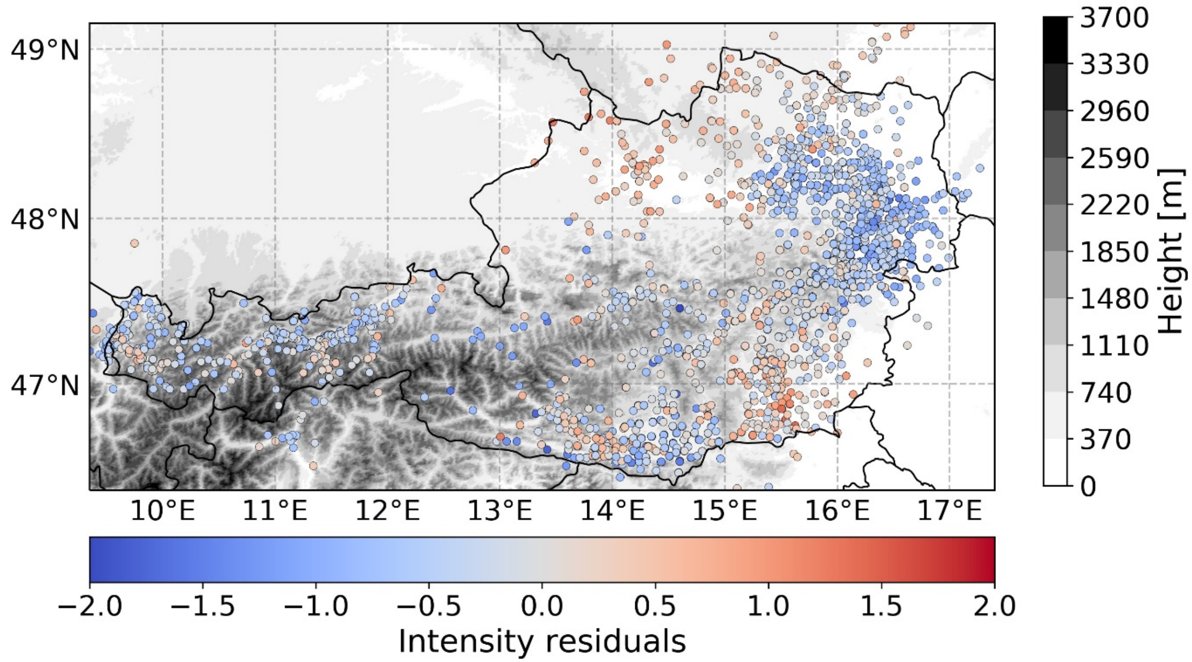
2.a) Epicentral intensity (I_0) calibration

Calculation:

$$I_{local} = k_0 + k_1 M_w + k_2 \ln(h) + c_0 \cdot \ln\left({}^{R}/_{h}\right)$$

I_0: Epicentral intensity
I_{local}: Local intensity
M_w: Moment magnitude
h: Focal depth [km]
R: Hypocentral dist. [km]

$k_0 = 2.56$
$k_1 = 1.32$
$k_2 = -0.94$
$c_0 = 1.05$
$\sigma(I_0) = \pm 0.26$
$\sigma(I_{local}) = \pm 0.50$



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2. Intensity Prediction Equation (IPE)

2.b.i) Local site response - Topography correction

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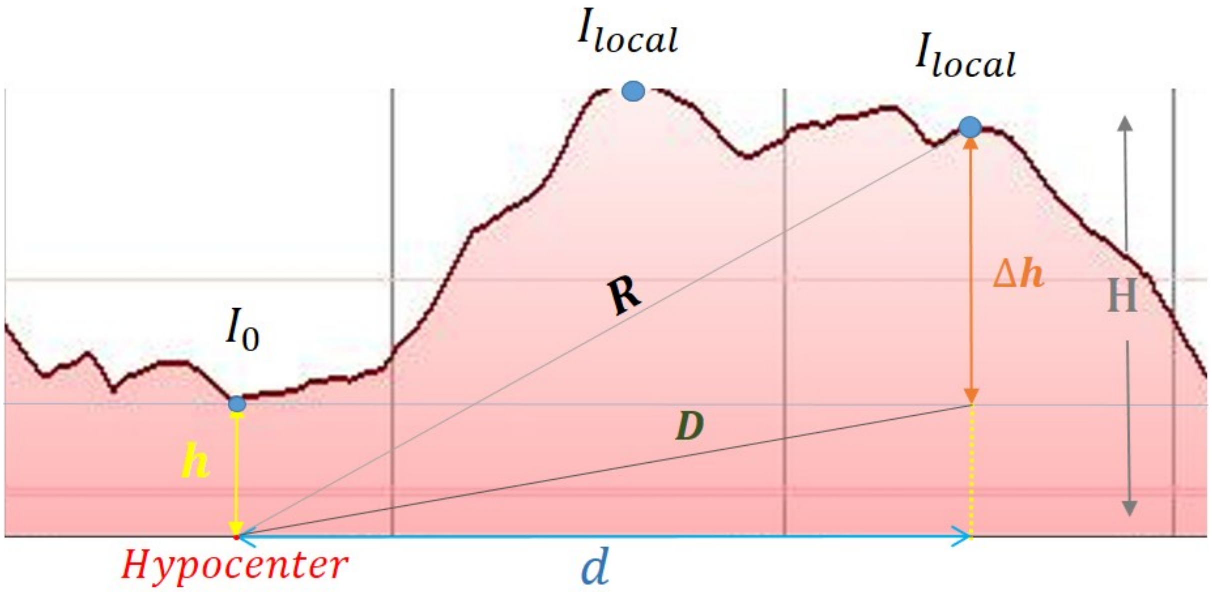
Waves travel further distances when they overcome a mountain than when they travel over moderate slope surfaces. This added distance is usually disregarded when deriving IPEs but taken into account when computing a topographic correction. In this study, we determined hypocentral distances (R) together with the altitude (Δh) of the IDP location based on a digital terrain model (DTM).



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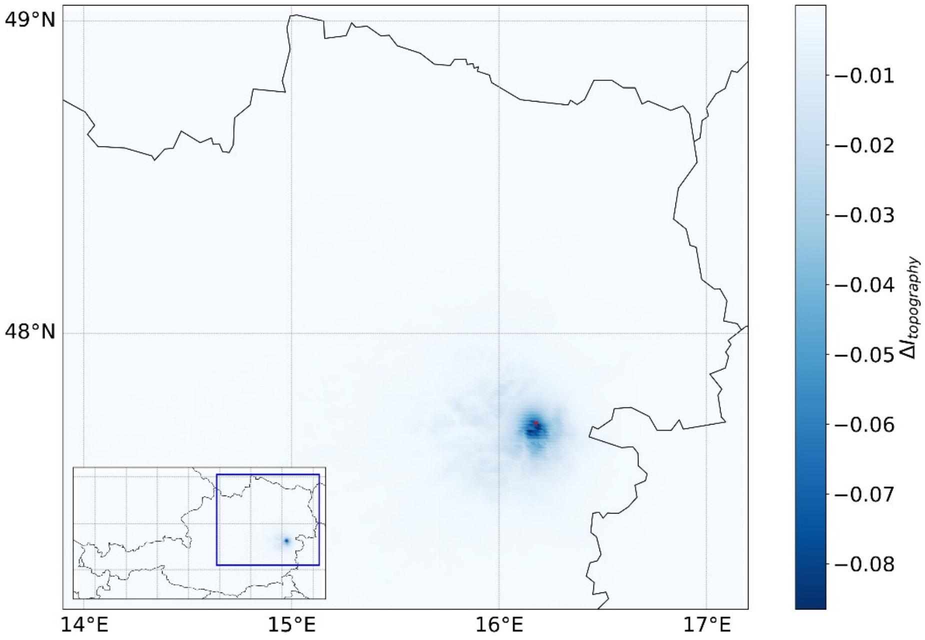
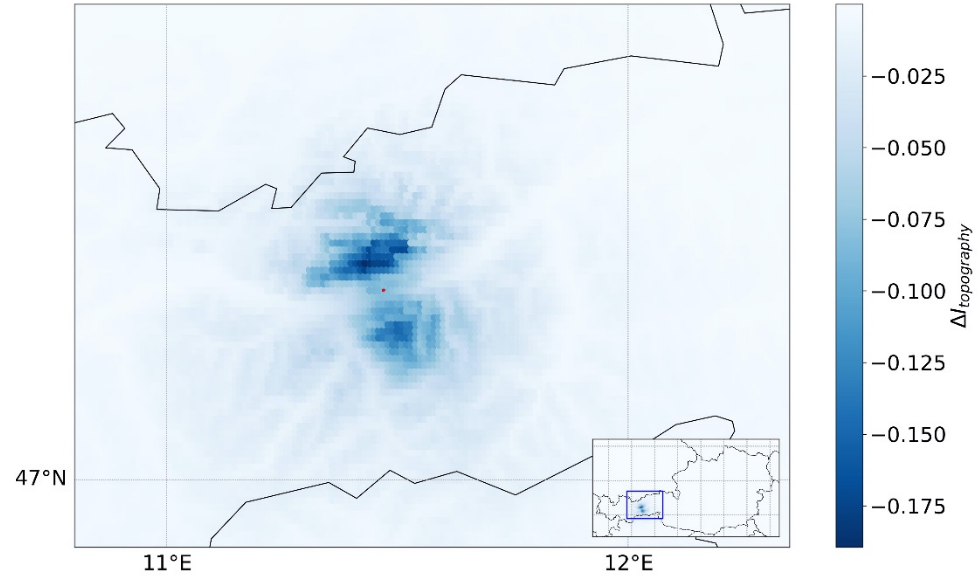
2.b.i) Local site response - Topography influence

As expected, the topography influence is more notorious in mountainous regions





Understandably, rather flat regions do not have a notable effect on the IPE results.

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2. Intensity Prediction Equation (IPE)

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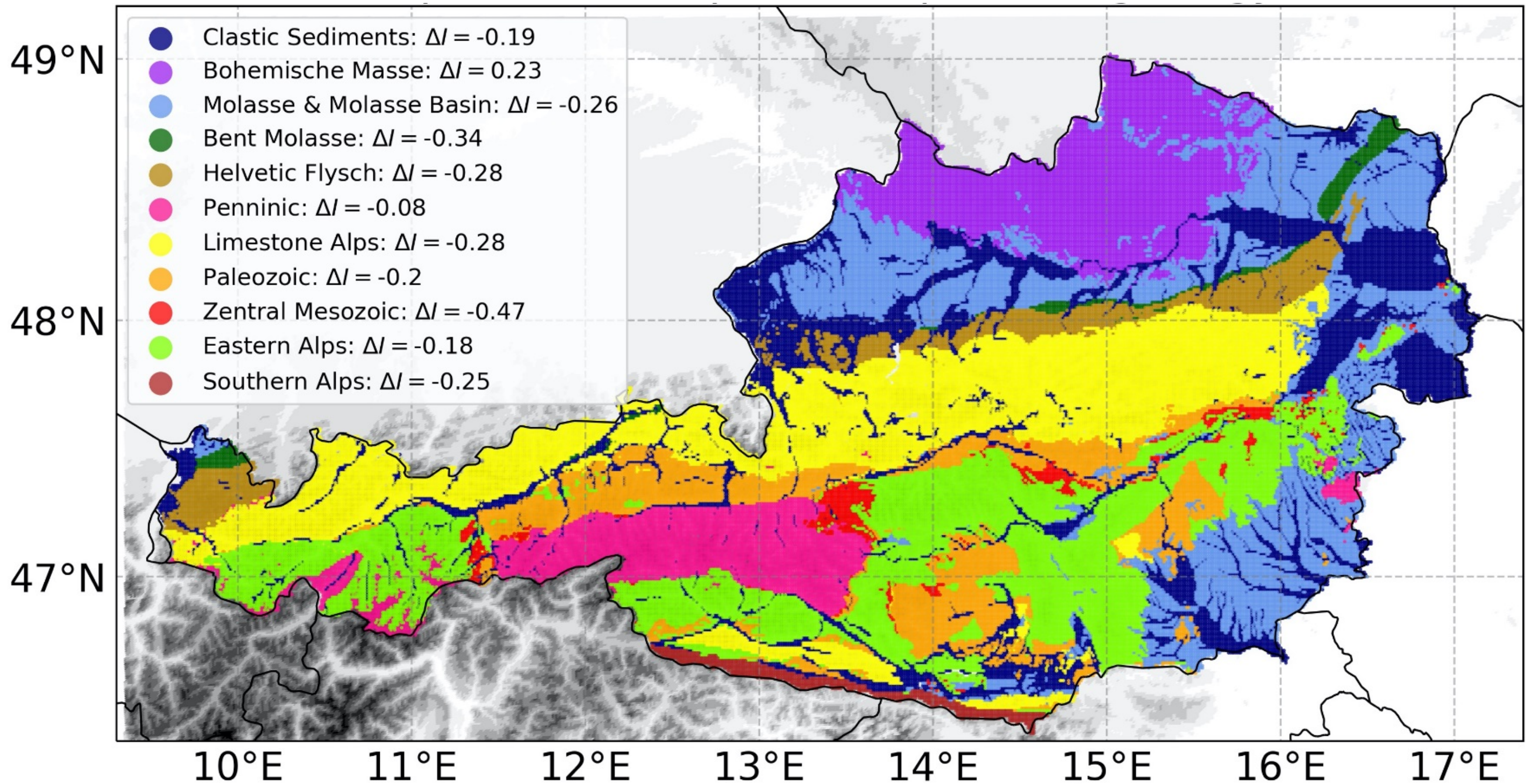
2.b.ii) Local site response - Geology correction



$$Res(I_{local}) = I_{local}^{model} - I_{local}^{IDP}$$

Correction range = 0.58

Negative residuals are noticeable in central and southern Austria.
To the North positive residuals are found.

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2. Intensity Prediction Equation (IPE)

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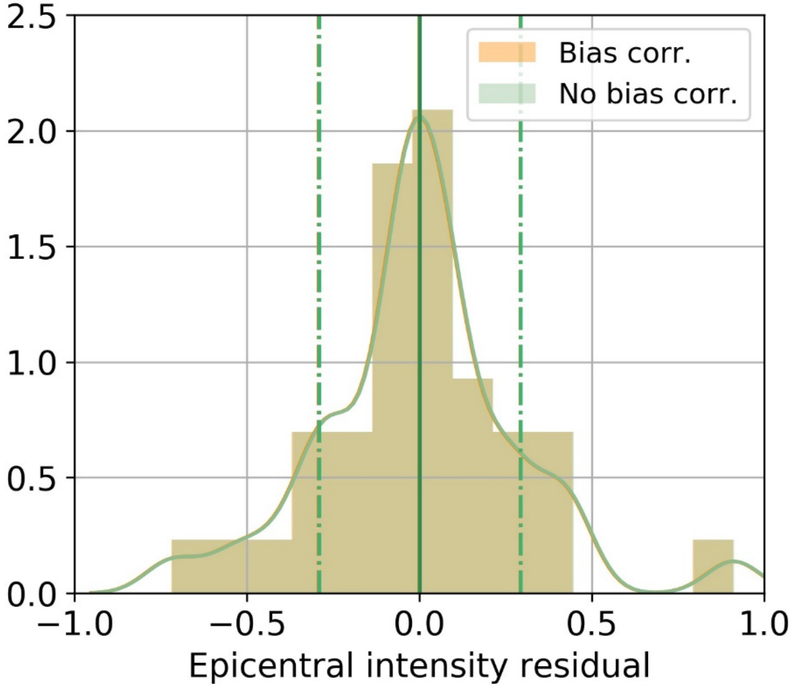
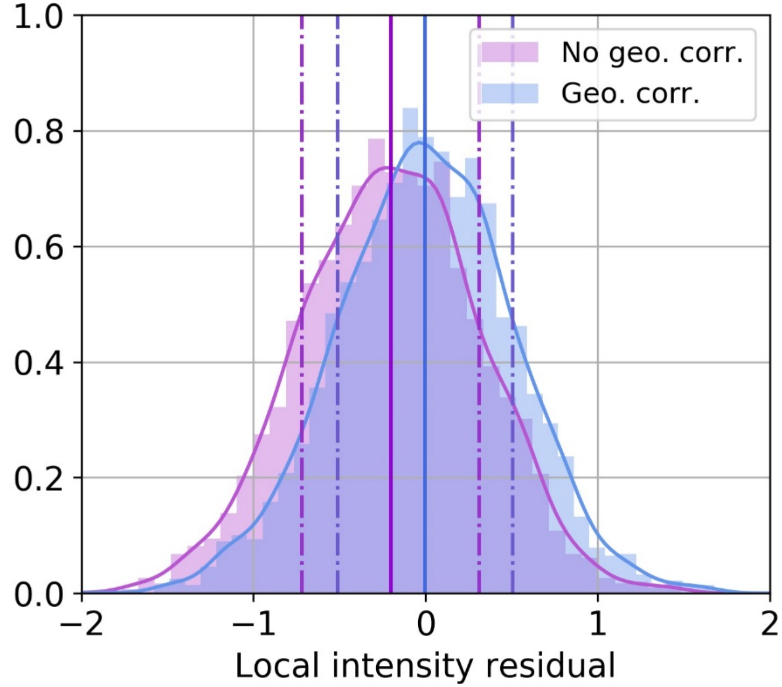
2.b.ii) Local site response - Geology correction

$$\overline{res}_{no\ Geo.} = 0.0$$
$$\overline{res}_{Geo.} = 0.0$$
$$\sigma_{res.no\ Geo.} = 0.26$$
$$\sigma_{res.no\ Geo.} = 0.26$$

$$\overline{res}_{no\ Geo.} = -0.20$$
$$\overline{res}_{Geo.} = 0.0$$
$$\sigma_{res.no\ Geo.} = 0.50$$
$$\sigma_{res.no\ Geo.} = 0.50$$





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Root Mean Square Error (RMSE) and Skill-Score (SS)

- To assess the relative improvement of the IPE over a reference value the Skill Score (Murphy 1988) of the RMSE was used.

- The common RMSE-SS (Murphy 1988) has a range between $-\infty$ and 1. However, in this study, the definition introduced by Atencia et al. (2019) was used.

$$RMSE - SS = \begin{cases} 1 - \dfrac{RMSE_{corr.}}{RMSE_{IPE}} & if \quad RMSE_{corr.} < RMSE_{IPE} \\ \dfrac{RMSE_{IPE}}{RMSE_{corr.}} - 1 & if \quad RMSE_{corr.} \geq RMSE_{IPE} \end{cases}$$

$RMSE_{IPE} \equiv$
Intensity values derived from the IPE with no correction

$RMSE_{corr.} \equiv$
Intensity values derived from the IPE with topography influence, geology correction or both

3. Model Verification

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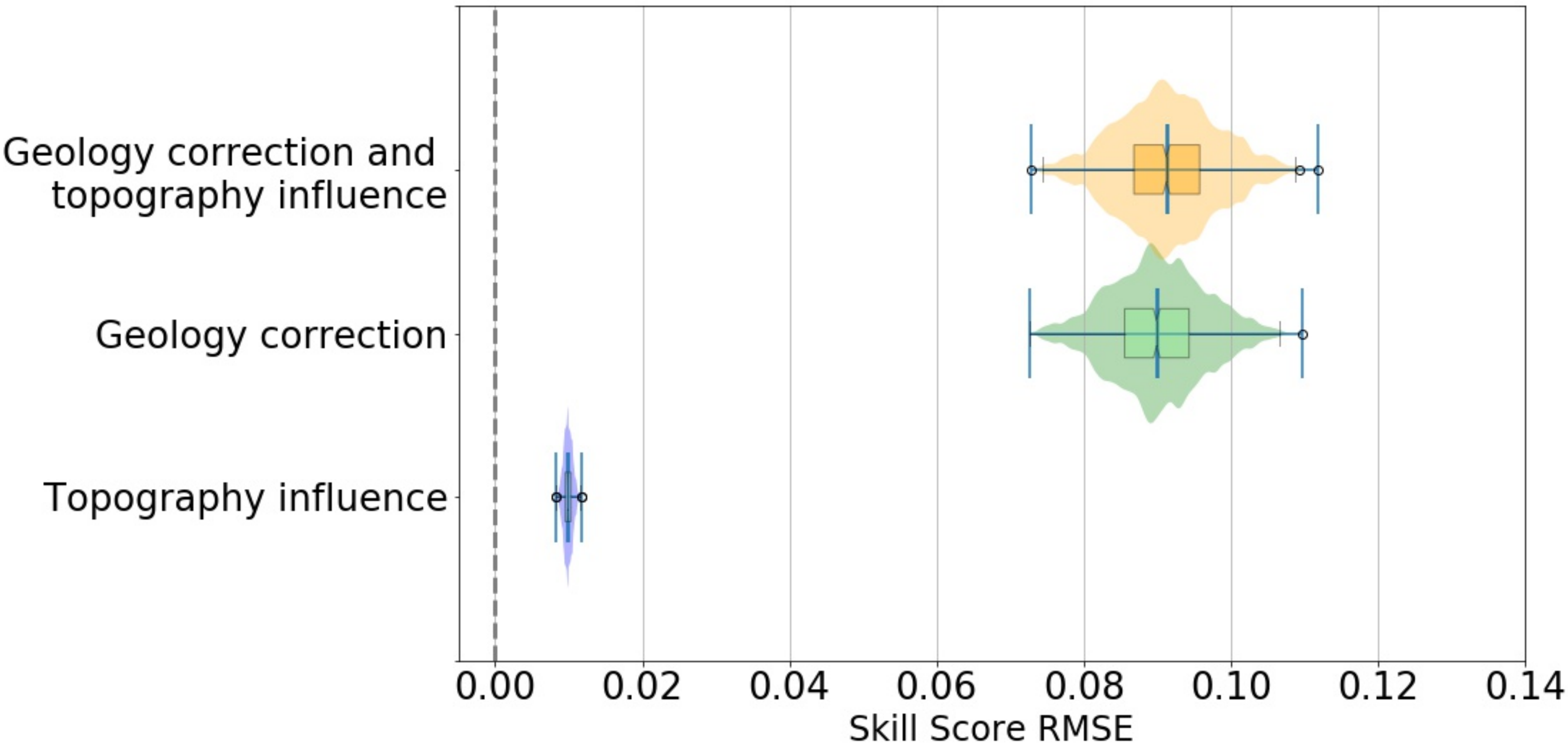
Same data set as for model calibration



Corrections regarding geology improve the IPE more than topographical corrections.

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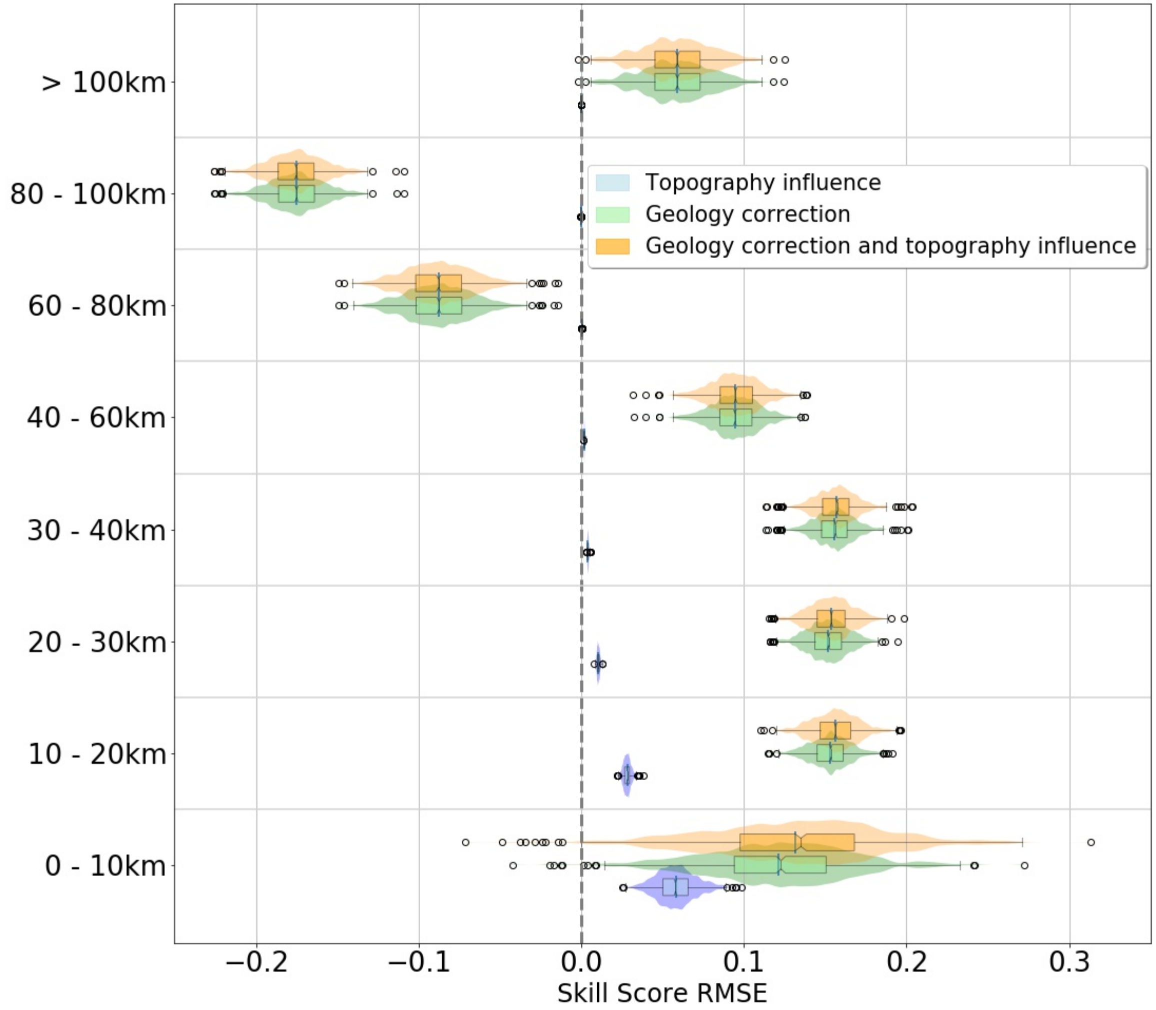
Slide 11

Same data set as for model calibration



The topography plays and important roll in epicentral regions and it looses influence with distance.

The geology correction is rather stable and has a positive improvement in the IPE but for distances from 60-100 km where it worsens the IPE results.

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3. Model Verification

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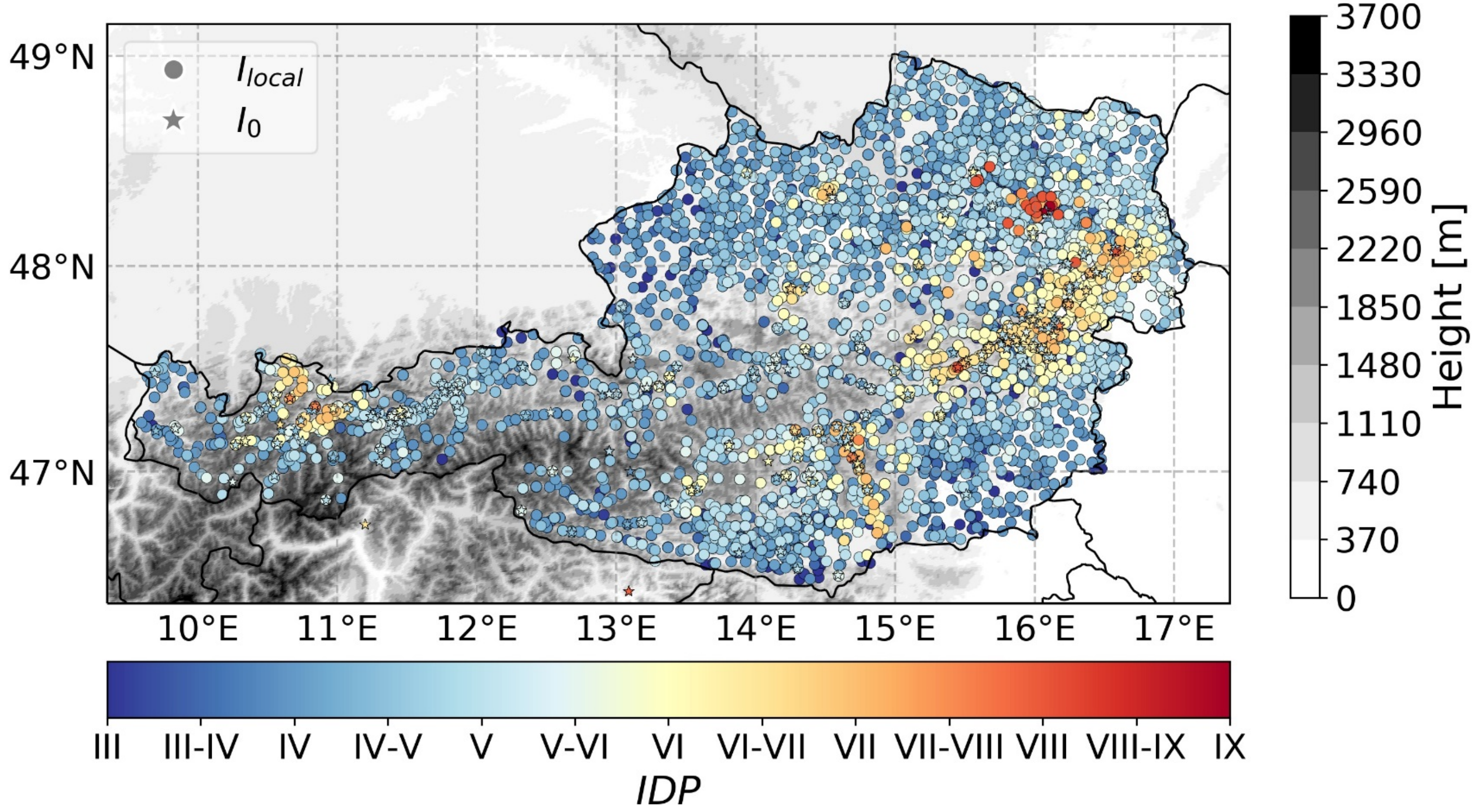
Verification period 1590-2004

250 earthquakes, with about 14.000 IDPs. The intensities vary from III to IX (EMS-98, Grünthal, 1998) and m_l ranges from 3.0 to 5.8.



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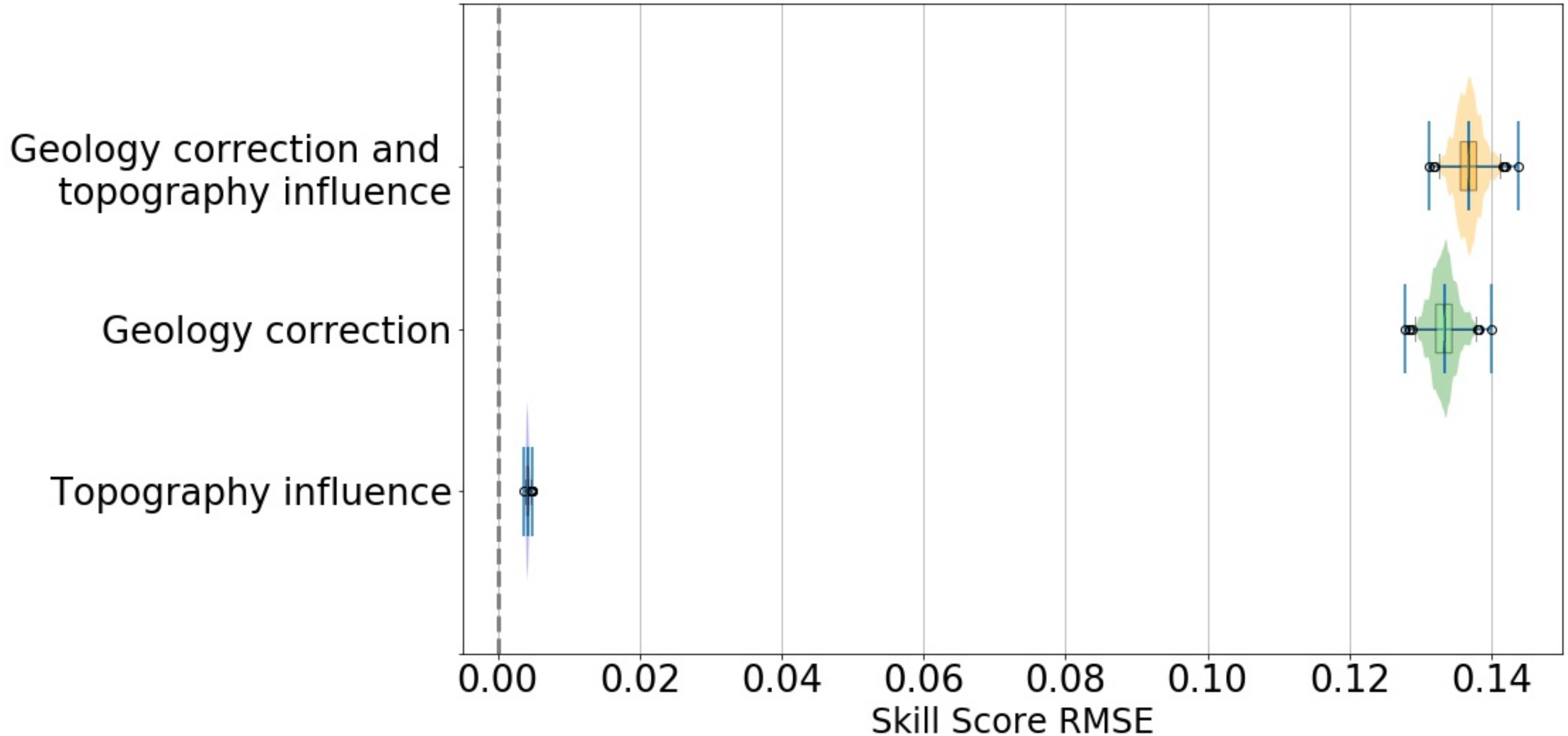

As for the calibration data set, a geology correction improves the IPE more than the topography influence, when separately applied.

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3. Model Verification

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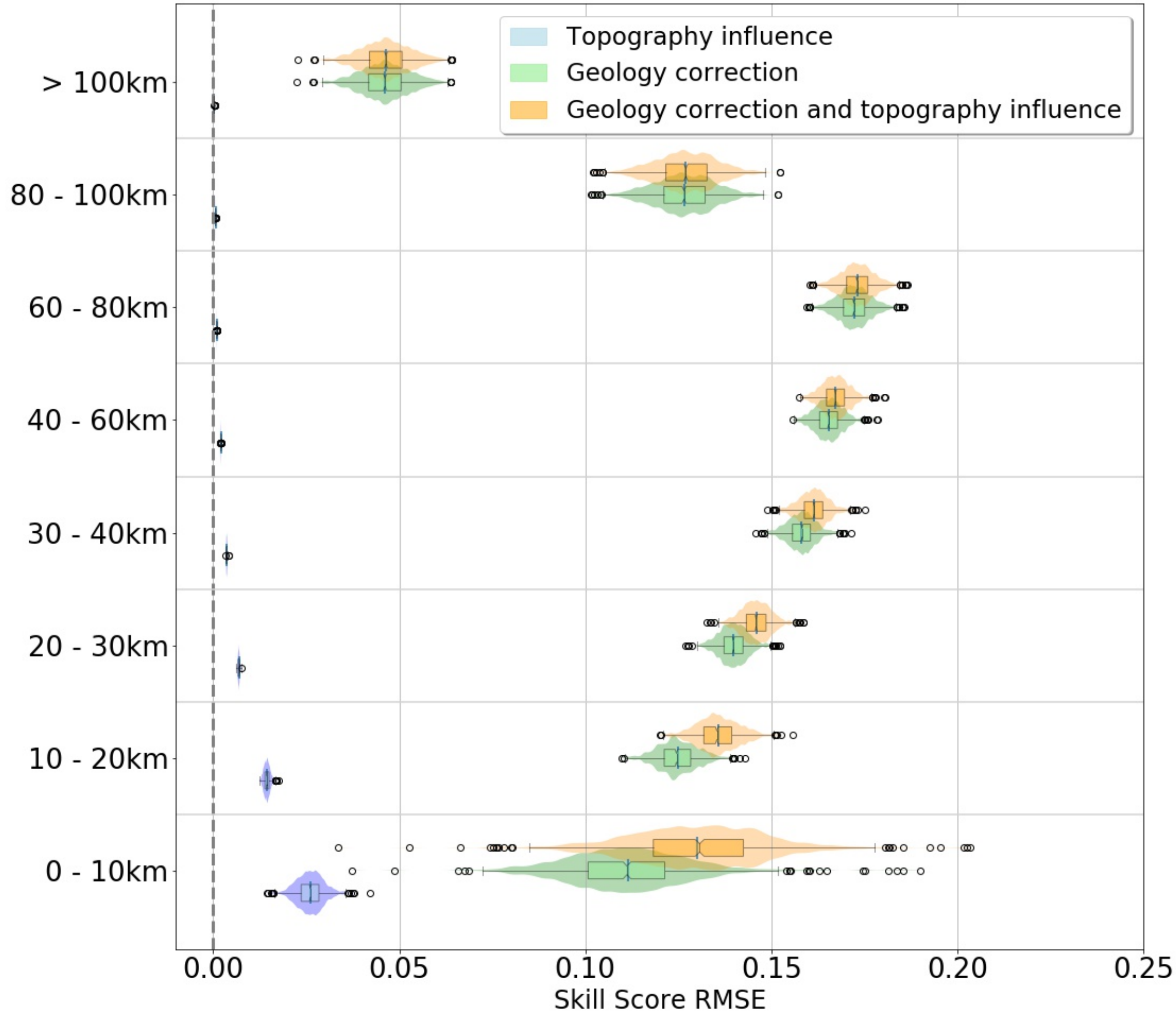
Verification period 1590-2004



As before, in epicentral regions, the topography plays a notable role and diminishes with increasing distance.

The 'geology correction' has always a positive improvement of the IPE.

Appling both corrections always improves the IPE.

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4. Real-Time ShakeMap

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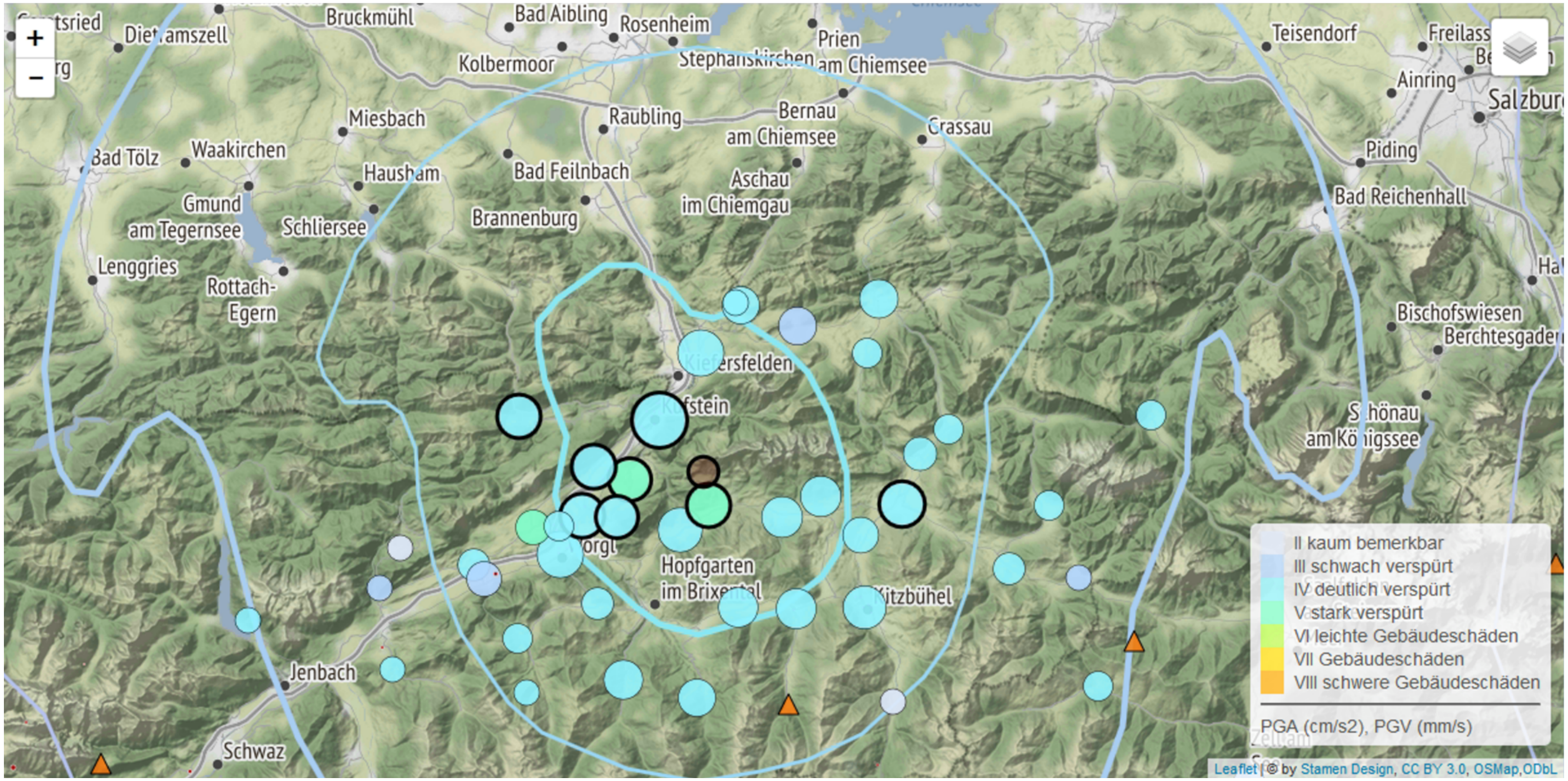
Earthquake on the 22nd of October 2019

$m_l = 3.9$ $I_0^{IPE} = I_0^{IDP} = V$ depth = 12km

Location: $12.2177°N, 47.5455°E$ Time: 23:35:40 LT



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5. Conclusions

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Conclusions - General

We may conclude that:

- The developed IPE describes very well contemporary and historical data.
- At larger distances from the epicenter the model fits the IDP values increasingly less (low local intensities with greater residuals) which can be attributed to local geological “anomalies”.
- Real-Time ShakeMaps were implemented for an early warning system and duty activities.
  A border region effect due to the absence of the geology correction outside of Austria was noticed.

5. Conclusions

Conclusions - General

The applied corrections improve the IPE results:

- The topography influence is more remarkable in regions close to the epicenter and for mountainous regions.
- The geology correction plays a more important role overall distances and correct for the IPE bias.
- Generally, when both, topography influence and geology correction, are applied the IPE improves.

6. Outlook

Current and future work

1. **Hazard map development**: the intensity based hazard map is currently being developed. For methodology, software and a the development accomplished until now I refer to Stefan Weginger's presentation in this session.
2. **Relationship of PGV/PGA and intensity shaking:** A relationship between GMPEs (PGV and PGA) and the developed IPE will be derived.
3. **Study of historical earthquakes in Austria:** We are currently developing machine learning algorithms to derive focal parameters from historical earthquakes aided by the presented IPE.