Intensity Prediction Equation for Austria: Applications and Analysis

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1. Macroseismic data set

Austrian Earthquake Catalog (period 2004-2018)

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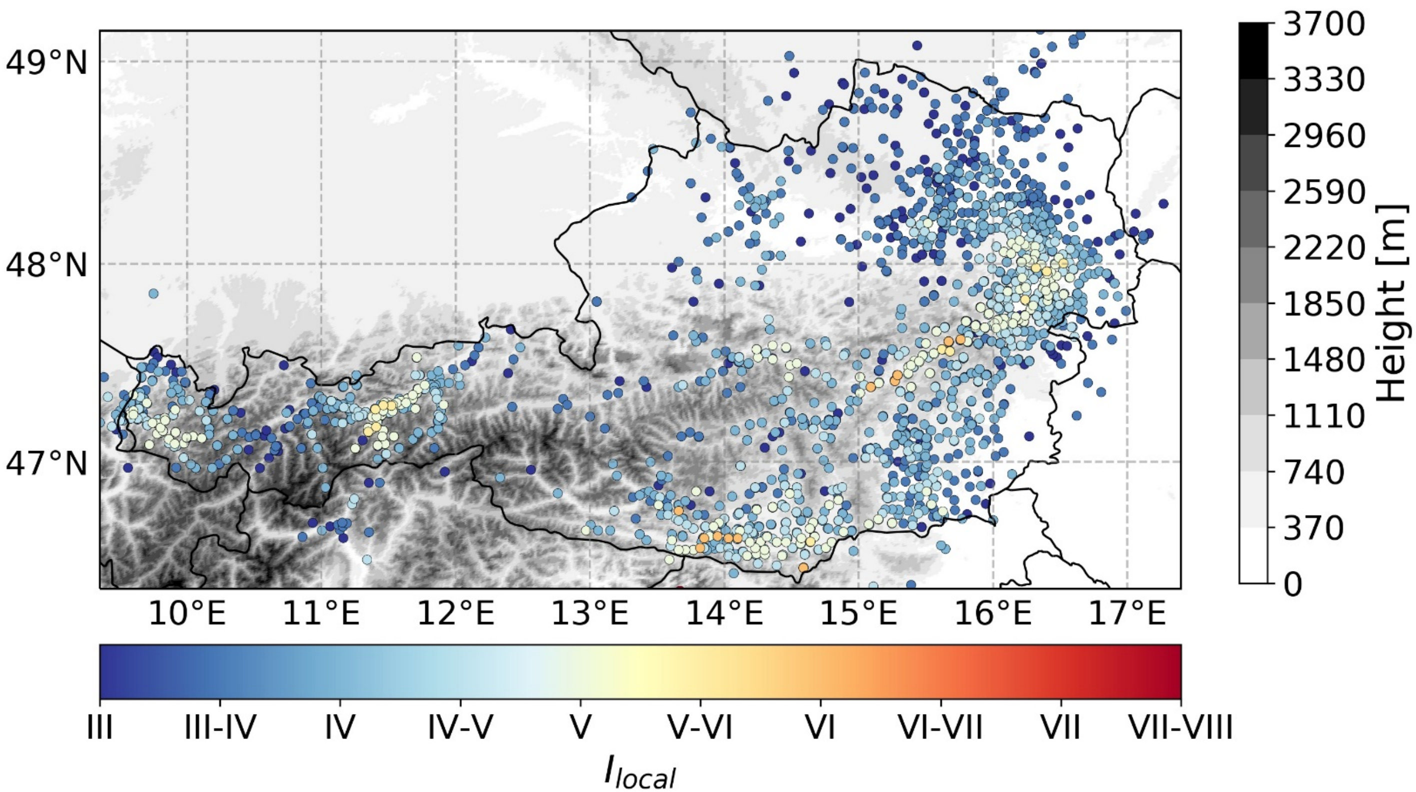
- 42 earthquakes with $3.0 \leq M_w \leq 5.4$ and 3,214 IDP's



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

2. Intensity Prediction Equation (IPE)

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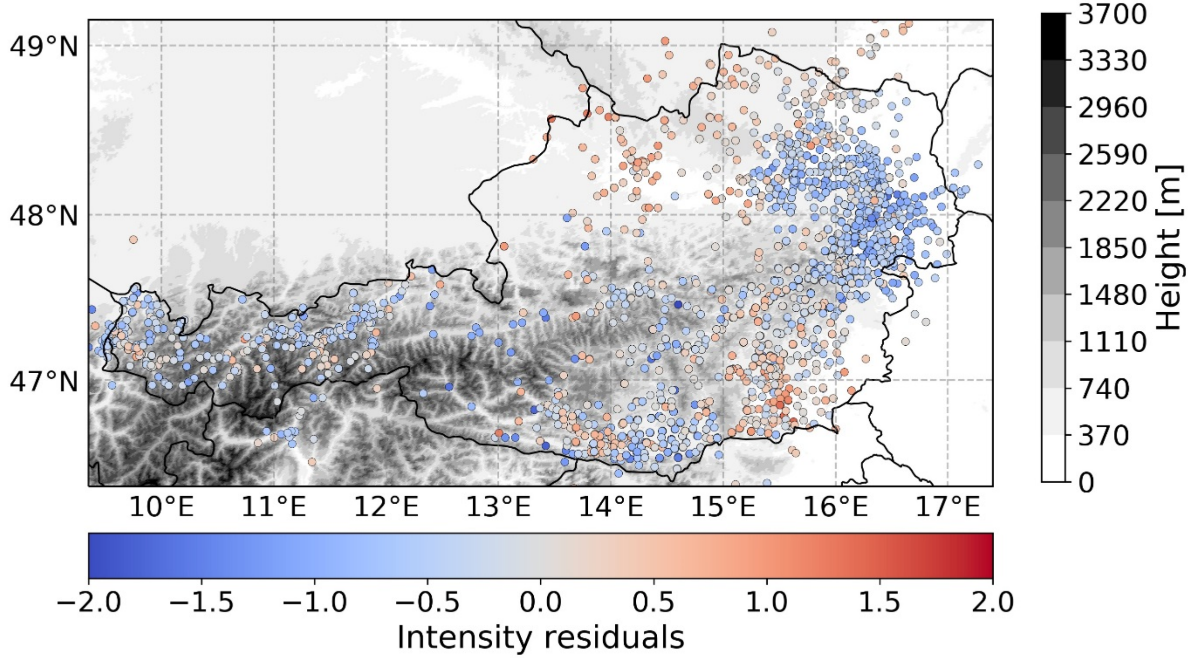
2.a) Epicentral intensity (I_0) calibration

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]

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



2. Intensity Prediction Equation (IPE)

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

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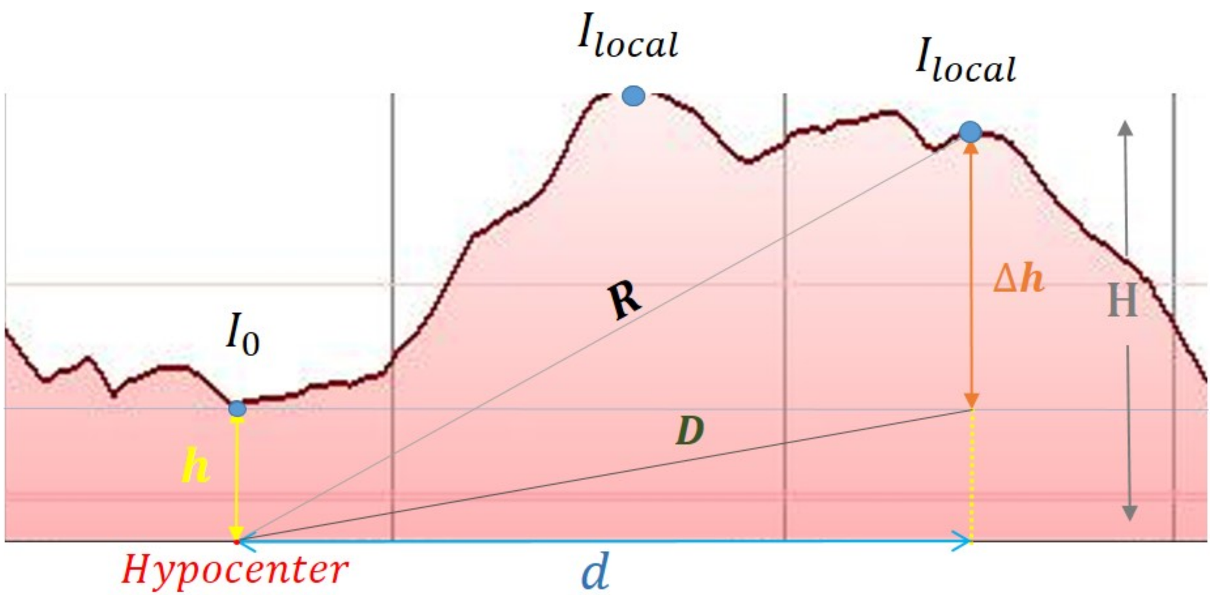
Waves travel further distances when they overcome a mountain than when they travel over moderate slope surfaces. This added distance is usually disregarded when deriving IPEs but taken into account when computing a topographic correction. In this study, we determined hypocentral distances (R) together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



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2. Intensity Prediction Equation (IPE)

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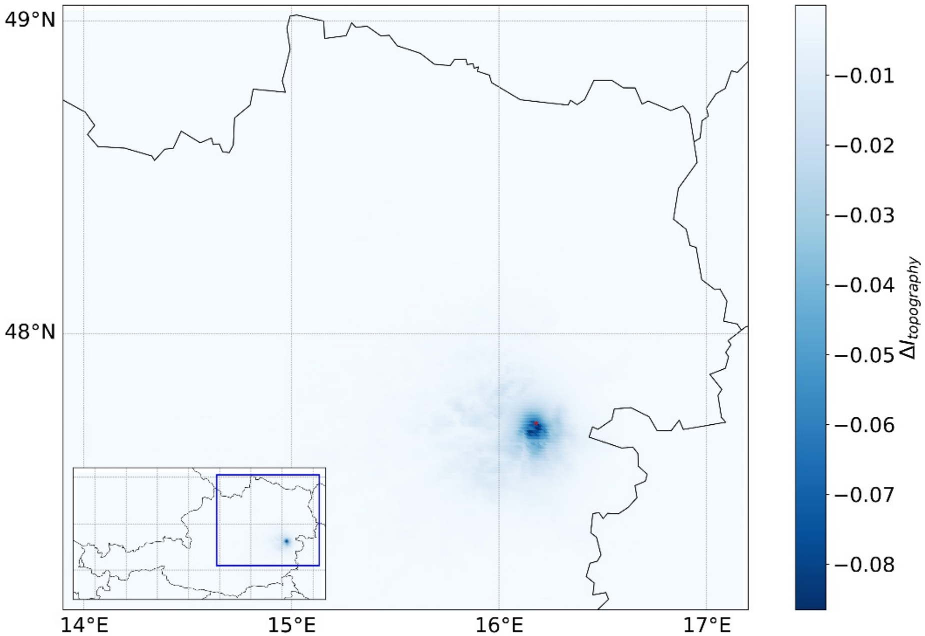
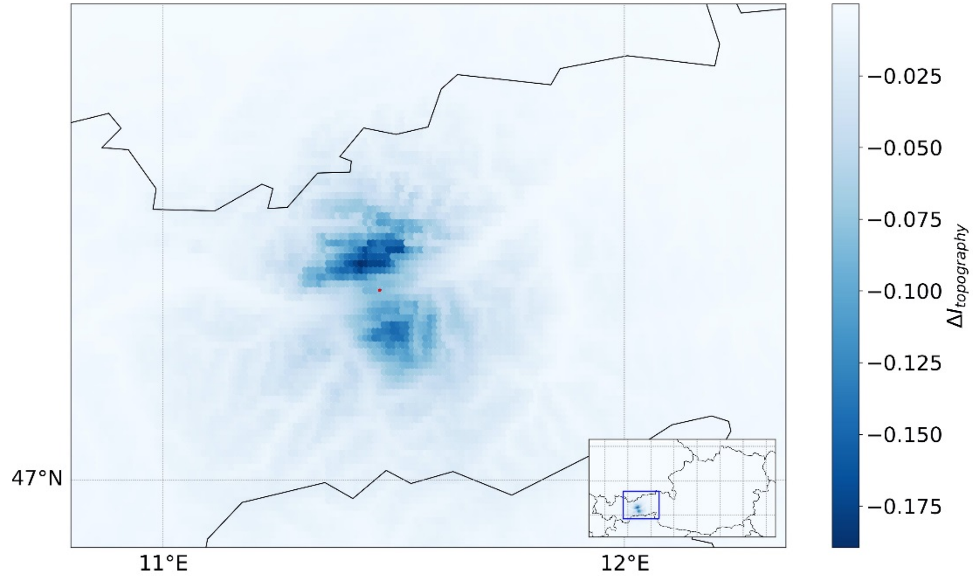
2.b.i) Local site response - Topography influence

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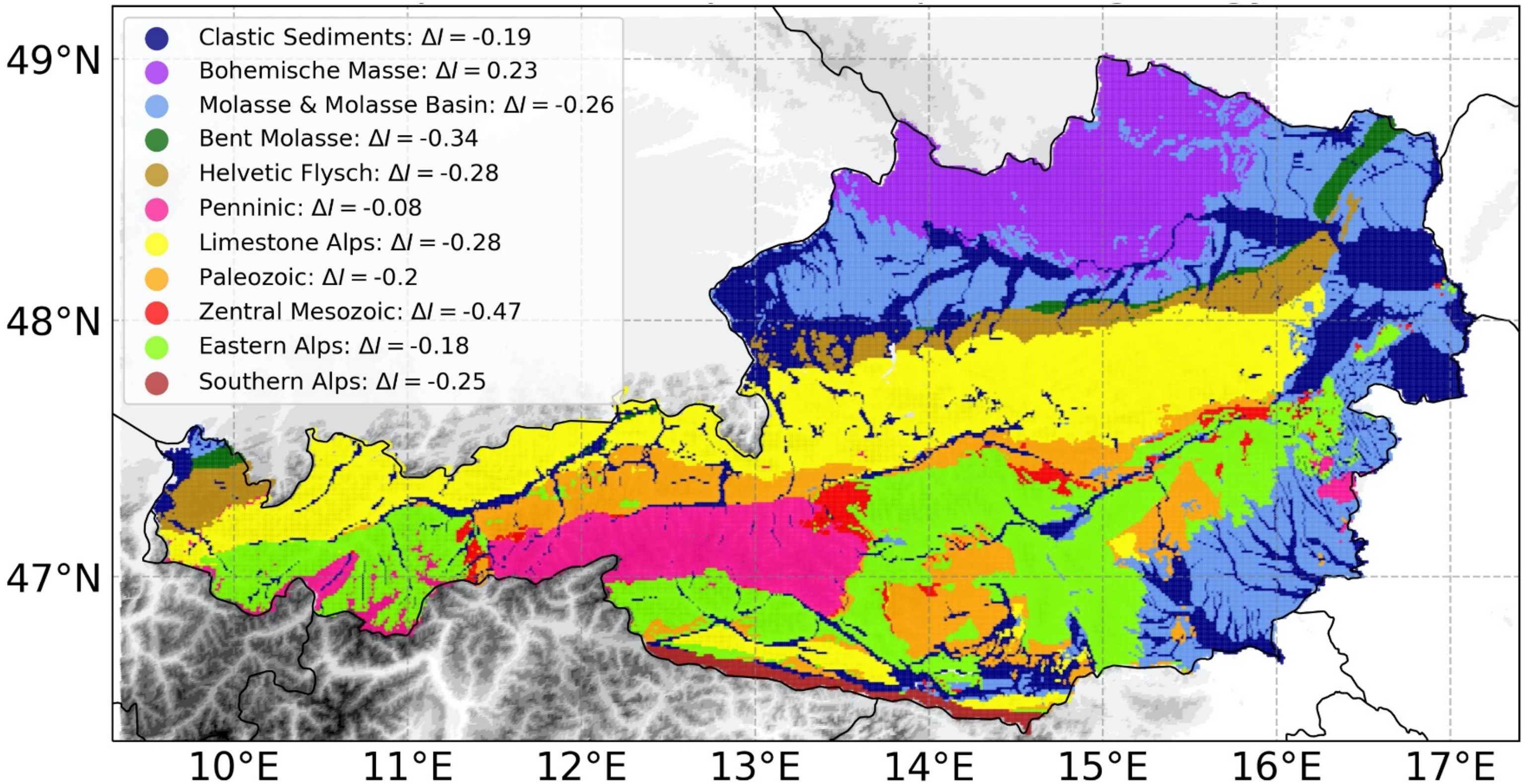
2.b.ii) Local site response - Geology correction



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

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

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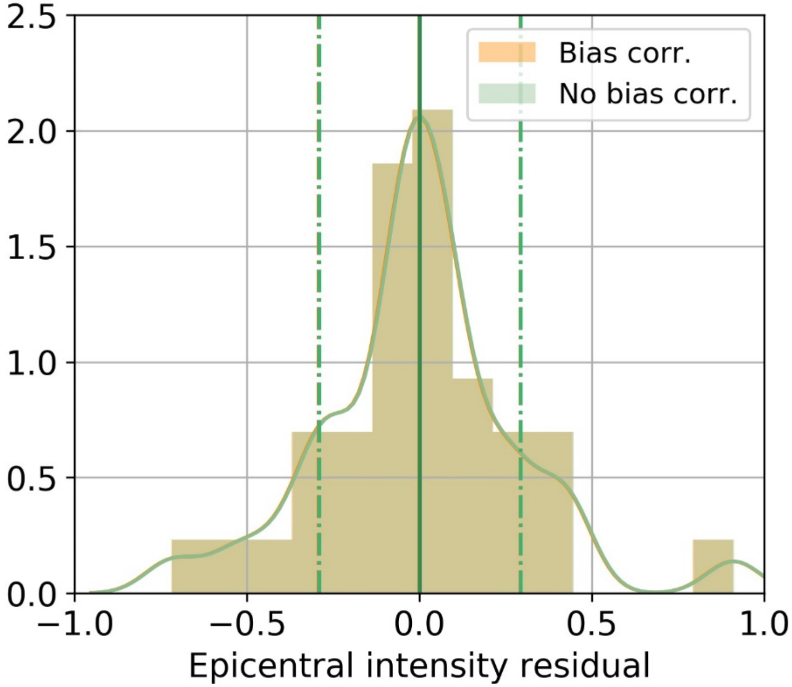
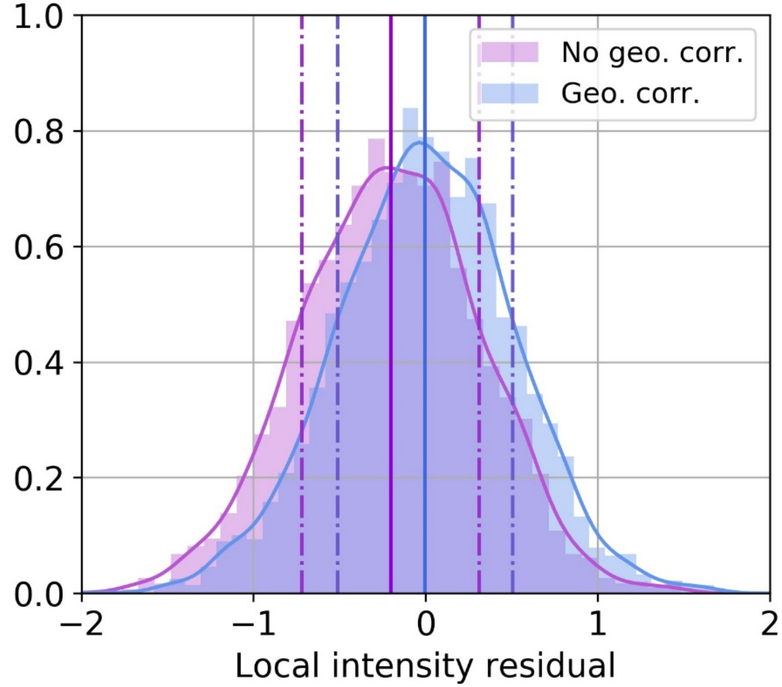
$$\overline{res}_{no\ Geo.} = 0.0$$
$$\overline{res}_{Geo.} = 0.0$$
$$\sigma_{res.no\ Geo.} = 0.26$$
$$\sigma_{res.no\ Geo.} = 0.26$$

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





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3. Model Verification

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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.

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

$RMSE_{IPE} \equiv$
$Intensity\ values\ derived\ from\ the\ IPE\ with\ no\ correction$
$RMSE_{corr.} \equiv$
$Intensity\ values\ derived\ from\ the\ IPE\ with\ topography\ influence, geology\ \ correction\ or\ both$

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3. Model Verification

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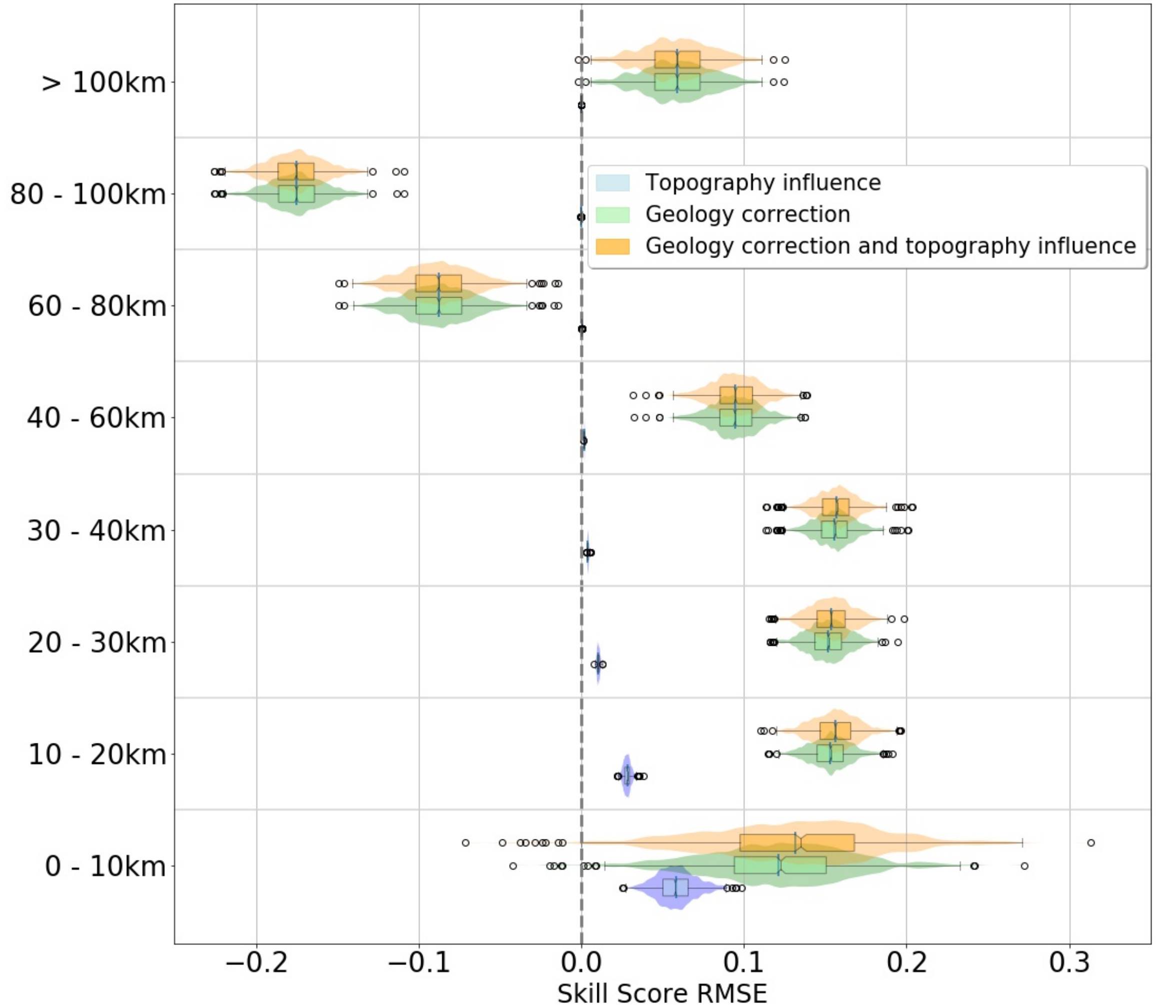
Same data set as for model calibration



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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4. Real-Time ShakeMap

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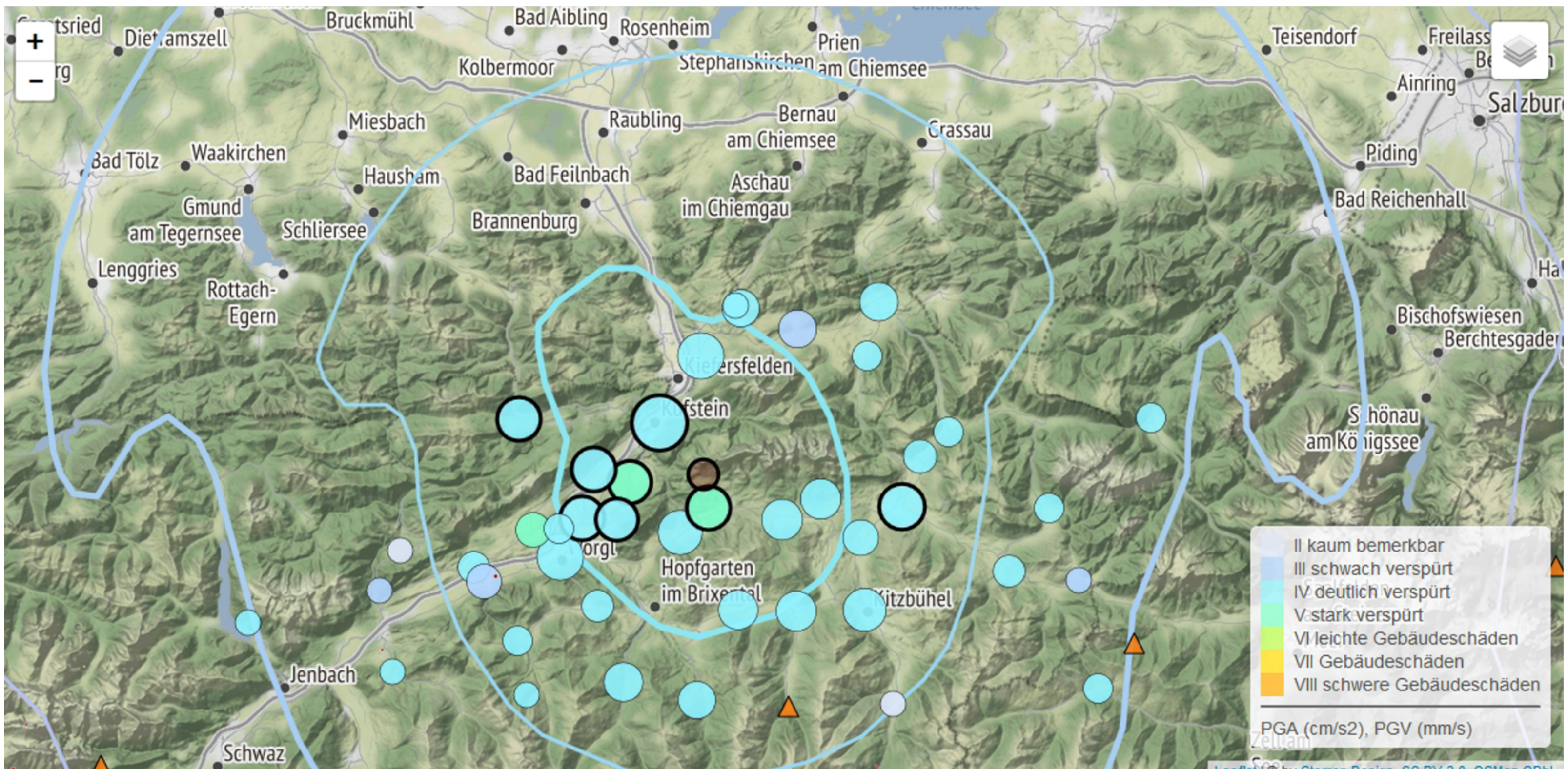
Earthquake on the 22nd of October 2019

$m_l = 3.9$ $I_0^{IPE} = I_0^{IDP} = V$ 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

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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

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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.

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