Intensity Prediction Equation for Austria: Applications and Analysis

**María del Puy Papí-Isaba**, Stefan Weginger, Maria-Theresia Apoloner, Yan Jia, Helmut Hausmann, Rita Meurers & Wolfgang Lenhardt

m.papi-isaba@zamg.ac.at
Contents

1. Macroseismic data set (Austrian catalog)
2. Intensity Prediction Equation (IPE)
   i. Epicentral intensity ($I_0$) calibration
   ii. Local site response
      a) Topography correction
      b) Geology correction
3. Model verification
4. Real-Time ShakeMaps
5. Conclusions
6. Outlook
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 $\geq$ III were considered

- At least 10 IDP’s.
2. Intensity Prediction Equation (IPE)

2.a) Epicentral intensity ($I_0$) calibration

**Calculation:**

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

$I_0$: 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

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).
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.
2. Intensity Prediction Equation (IPE)

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

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

\[
Res(I_{local}) = I^{model}_{local} - I^{IDP}_{local}
\]

Correction range = 0.58
2. Intensity Prediction Equation (IPE)

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

\[
\overline{\text{res}}_{\text{no Geo.}} = 0.0 \\
\overline{\text{res}}_{\text{Geo.}} = 0.0 \\
\sigma_{\text{res.no Geo.}} = 0.26 \\
\sigma_{\text{res.no Geo.}} = 0.26
\]

\[
\overline{\text{res}}_{\text{no Geo.}} = -0.20 \\
\overline{\text{res}}_{\text{Geo.}} = 0.0 \\
\sigma_{\text{res.no Geo.}} = 0.50 \\
\sigma_{\text{res.no Geo.}} = 0.50
\]
3. Model Verification

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.

\[
RMSE - SS = \begin{cases} 
1 - \frac{RMSE_{corr.}}{RMSE_{IPE}} & \text{if } RMSE_{corr.} < RMSE_{IPE} \\
\frac{RMSE_{IPE}}{RMSE_{corr.}} - 1 & \text{if } RMSE_{corr.} \geq RMSE_{IPE}
\end{cases}
\]

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

\[
RMSE_{corr.} \equiv Intensity \ values \ derived \ from \ the \ IPE \ with \ topography \ influence, \ geology \ correction \ or \ both
\]
3. Model Verification

Same data set as for model calibration

Corrections regarding geology improve the IPE more than topographical corrections.
The topography plays an important role in epicentral regions and it loses 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.
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.
As for the calibration data set, a geology correction improves the IPE more than the topography influence, when separately applied.
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.

Applying both corrections always improves the IPE.
4. Real-Time ShakeMap

Earthquake on the 22\textsuperscript{nd} of October 2019

\[ m_l = 3.9 \quad I_0^{IP} = I_0^{ID} = V \]

Location: 12.2177°N, 47.5455°E

Time: 23:35:40 LT

Depth = 12km
5. Conclusions

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 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.