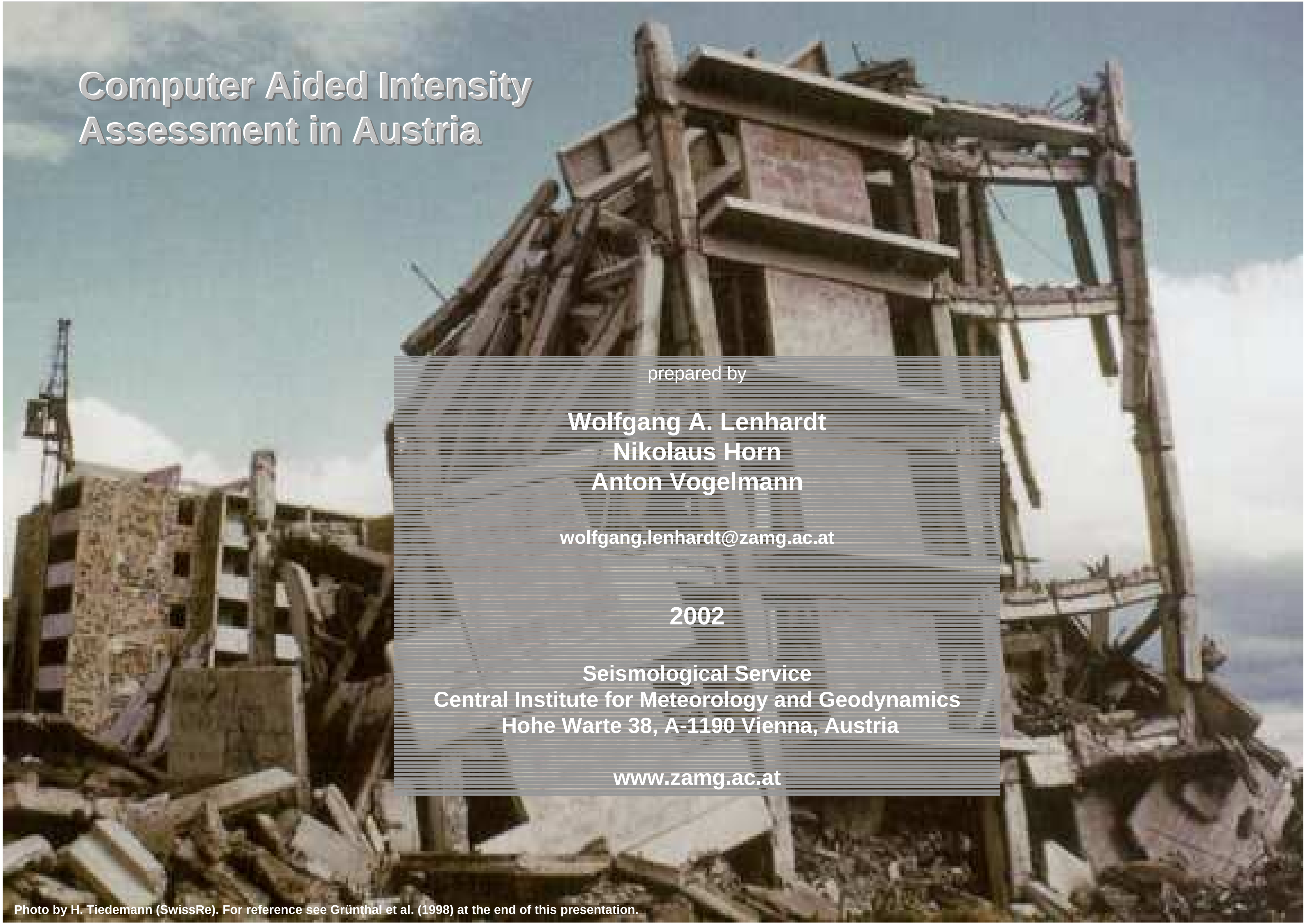

Computer Aided Intensity Assessment in Austria

prepared by

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Photo by H. Tiedemann (SwissRe). For reference see Grünthal et al. (1998) at the end of this presentation.

Motivation

In June 2001 the Seismological Service of Austria has put a questionnaire (in German) on the world wide web to collect responses from the community regarding the observed effects from seismic tremors. The feed-back was exciting and several 100’s of questionnaires - even from extreme remote areas - were received via the internet.

Therefore, we decided to develop tools for automatically evaluating the data and to publish the results in future in 30’ minute-intervals on the internet to keep the civil protection units and the public informed.

Meanwhile, countries like Switzerland (4 languages), Germany (German), Italy (2 questionnaires, one in Italian and one in Italien/English), Slovenia (Slovenian) and Slovakia (Slovakian) have put questionnaires on the world-wide web.

Task 1:
Determining a ‚community intensity‘

Task 2:
Mapping of data and data-exchange across borders

Approach

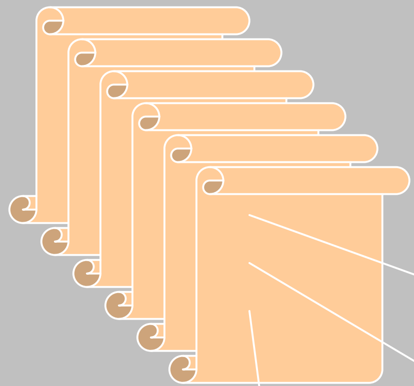
A questionnaire addresses three **categories** of macroseismic effects:

1. Human perception
2. Objects
3. Damage to buildings

A set of questionnaires from a particular region allows to separate the percentage of reported effects in different **groups** in terms of few, many and most.

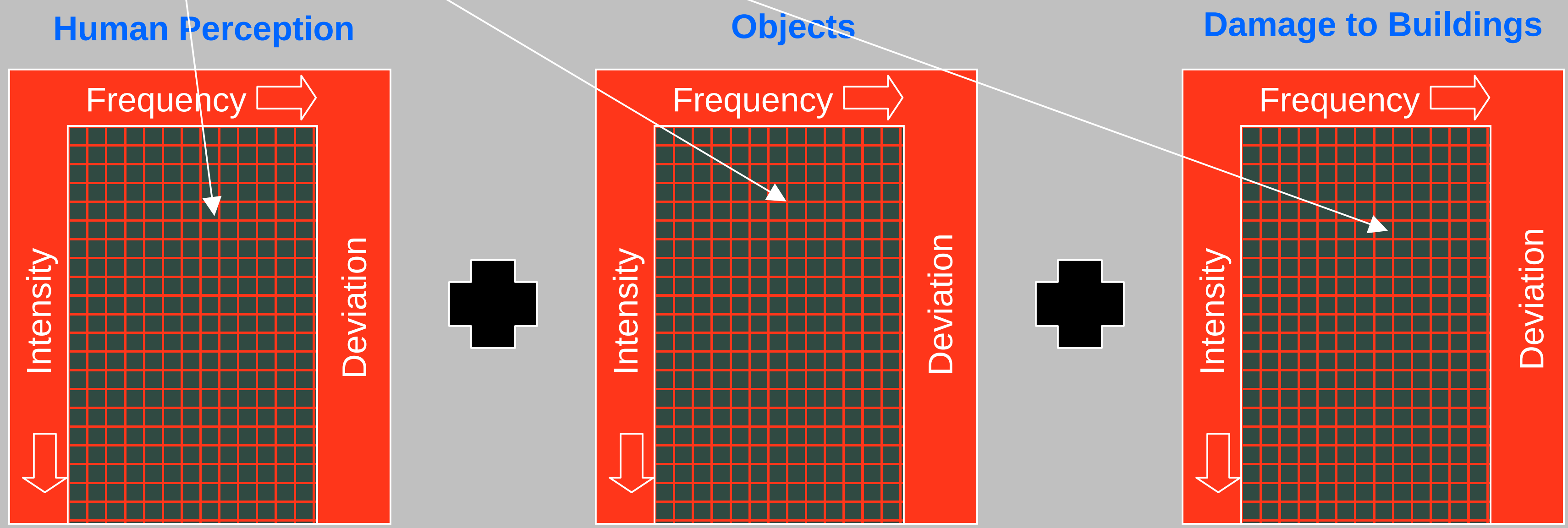
Definition of ‚perfect‘ percentages of groups:
Very Few = 0,5 %
Few = 10 - 10,5 %
Many = 40 %
Most = 80 %
ManyMost = 60 %

Approach – cont‘d



The entries of a set of questionnaires are allocated to specific cells corresponding to one of the three **categories** (matrices):

1. **Human perception**
2. **Objects**
3. **Damage to buildings**



The calculated deviations are added. The row with the lowest total deviation is declared as ‚community intensity‘.

Principle of a Matrix

Entries in the questionnaires are allocated to appropriate cells (column and row) of the respective matrix of a specific category.

Position in Matrix	Legend
R	Effect 1
S	Effect 2
T	Effect 3
U	Effect 4
V	Effect 5
W	Effect 6
X	Effect 7

EMS-98	Very few (< 1%)	Few (1% - 20%)	Many (20% - 60%)	Most (> 60%)	Calculated Deviation
1	-	-	-	-	
2	R , T	-	-	R*	
3	-	S , T	R		
4	W	U	S		
5	-	W , X	U	S , V	
6	-	Y	W , X	S	
7	-	-	Y , Z	W , X	
8	-	-	Z	-	
9	-	-	-	Z	
10	-	-	-	-	
11	-	-	-	-	
12	-	-	-	-	

By adding entries of other questionnaires, the matrix is completed.

Determining the Intensity

Deviations are calculated from the deviations from the perfect percentages from n-entries (questionnaires):

$$\text{deviation} = \text{weight} * \sum_{1}^{n} \frac{\text{observed value} - \text{central value}}{\text{width}}$$

The smallest deviation in each category (human perception, objects, building damage) indicates the most appropriate intensity for that particular category.

Human Perception Matrix

EMS-98	Very few (< 1%)	Few (1% - 20%)	Many (20%-60%)	Most (> 60%)
1	-	-	-	-
2	R , T	-	-	R*
3	-	S , T	R	
4	W	U	S	
5	-	W , X	U	S , V
6	-	Y	W , X	S
7	-	-	Y , Z	W , X
8	-	-	Z	-
9	-	-	-	Z
10	-	-	-	-
11	-	-	-	-
12	-	-	-	-

Position in Matrix	Legend
R, R*	Felt at rest, * only in upper floors
S	Indoors
T	Slight trembling
U	Awake
V	Strong trembling
W	Outdoors
X	Frightning
Y	Balance, upper floors
Z	Balance

Human Perception Matrix - cont‘d

Note:

The perception of tremors reported by humans is restricted to intensity degrees ranging from 2 to 9, but covers a large part of the intensity range.

Object Matrix

EMS-98	Few (< 20%)	Many/ Most (> 20%)
1	-	-
2	-	-
3	-	H
4	J	I
5	L	K
6	N	M
7	-	O
8	-	P
9	-	-
10	-	-
11	-	-
12	-	-

Position in Matrix	Legend
H	Hanging objects swing slightly
I	Hanging objects swing, glasses, windows & doors rattle, light furniture shakes visibly
J	Light furniture shakes visibly, woodwork creaks
K	Hanging objects swing considerable, Glasses clatter, windows & doors open and shut, light top heavy objects shift or fall, animals indoors may become uneasy, liquids oscillate and may spill
L	Window panes break
M	Small objects may fall and furniture may be shifted, farm animals may be frightened
N	Dishes and glassware may brake
O	Furniture is shifted, top-heavy furniture may be overturned, objects fall from shelves, water splashes from containers, tanks and pools
P	Furniture may be overturned. Heavy objects (TV sets, typewriters) fall down.

Objects Matrix - cont'd

Note:

The observation of objects is restricted to intensity degrees ranging from 3 to 8 according to the EMS-98.

Obviously all hanging objects would also swing above intensity 5, and standing objects would topple at intensities beyond 8.

Effects observed in nature are discarded in the automatic evaluation.

Damage Matrix

Four building categories can be found in Austria‘s questionnaire:

1) ‚Feldstein- oder Lehmziegelbau‘ = ‚rubble stone, fieldstone, adobe‘
2) ‚Ziegelbau, Fertigteilbau, Fachwerkbau, Bau aus bearbeiteten Natursteinen‘ = ‚masonry in a broad sense‘
3) ‚Stahlbetonbau, Konstruktion mit vorgespannten Betonskelett‘ = ‚RC structures‘
4) ‚Holzbau‘ = ‚timber structures‘

Together with the building condition- a parameter which is asked for in the national questionnaire – is allocated to the most likely vulnerability class, ranging from A - E:

Vulnerability Classes

Building Category

Condition	1)	2)	3)	4)
Above average*	B	C	E	E
Good	A	B	D	D
Bad	A	A	C	C

Most likely in Austria, if no specific information is given in the questionnaire. In such a case, the default will be vulnerability class ‚C‘.

Note, that vulnerability class ‚F‘ is not present here, for it is not one of the most likely ones, - and categories 3) and 4) are identical in terms of the vulnerability.

*= strengthened, adhering to most recent building code

Damage Matrix – cont‘d

First, we have to count the cases in each damage grade/vulnerability class and express them in percentages.

Note: Vulnerability class ‚B‘ and damage ‚2‘ is labelled as ‚B2‘, and so on.

EMS-98	Few (< 20%)	Many (20% - 60%)	Most (> 60%)
1	-	-	-
2	-	-	-
3	-	-	-
4	-	-	-
5	A1, B1	-	-
6	A2, B2, C1	A1, B1	-
7	A4, B3, C2, D1	A3, B2	-
8	A5, B4, C3, D2	A4, B3, C2	-
9	B5, C4, D3, E2	A5, B4, C3, D2	-
10	C5, D4, E3, F2	B5, C4, D3, E2	A5
11	D5, E4, F3	C5, D4, E3, F2	B5, C4, D3
12	-	-	A5, B5, C5, D5, E5, F5

Damage Matrix - cont‘d

Note:

The observation of damages is restricted to intensity degrees ranging from 5 to 12 according to the EMS-98.

Determining the Intensity –cont‘d

Deviations are determined for the three categories ‚human perception, ‚objects‘ and ‚building damage‘ according to:

Human Perception

$$\text{deviation} = \frac{W_1}{k_0}\left(k_1\frac{|VeryFew-0{,}5|}{0{,}5} + k_2\frac{|Few-10{,}5|}{9{,}5} + k_3\frac{|Many-40|}{20} + k_4\frac{|Most-80|}{20} + k_5\right)$$

Objects

$$\text{deviation} = \frac{W_2}{k_0}\left(k_1\frac{|Few-10|}{10} + k_2\frac{|ManyMost-60|}{40} + k_3\right)$$

Damage to Buildings

$$\text{deviation} = \frac{W_3}{k_0}\left(k_1\frac{|Few-10|}{10} + k_2\frac{|Many-40|}{20} + k_3\frac{|Most-80|}{20} + k_4\right)$$

For each intensity grade the deviations from representative frequencies are determined and added up. The intensity with the lowest deviation is declared as ‚community intensity‘.

Constants

The following constants are needed to calculate the deviations:

EMS-98	Human Perception						Objects				Damage				
	k0	k1	k2	k3	k4	k5	k0	k1	k2	k3	k0	k1	k2	k3	k4
1	1	0	0	0	0	1	1	0	0	1	1,0	0	0	0	1
2	5	1	0	0	1	0	1	0	0	1	1,0	0	0	0	1
3	7,10526	0	1	1	1	0	1,5	0	1	0	1,0	0	0	0	1
4	8,10526	1	1	1	1	0	2,5	1	1	0	1,0	0	0	0	1
5	7,10526	0	1	1	1	0	2,5	1	1	0	1,0	1	0	0	0
6	7,10526	0	1	1	1	0	2,5	1	1	0	3,0	1	1	0	0
7	6	0	0	1	1	0	1,5	0	1	0	3,0	1	1	0	0
8	2	0	0	1	0	0	1,5	0	1	0	3,0	1	1	0	0
9	4	0	0	0	1	0	1	0	0	1	3,0	1	1	0	0
10	1	0	0	0	0	1	1	0	0	1	7,0	1	1	1	0
11	1	0	0	0	0	1	1	0	0	1	7,0	1	1	1	0
12	1	0	0	0	0	1	1	0	0	1	4,0	0	0	1	0

A ‚1‘ occupies cells, which are addressed in the EMS-98.

Example

From a specific region, the returned questionnaires from an earthquake, which happened close to midnight, gave the following impression:

Total returns:
100

Human perception:
Felt indoors by 90, 40 woke up, 10 felt it outdoors, 20 were running outdoors, 10 were frightened of which 5 were not only frightened but also ran outdoors.

Objects:
50 reported lamps swinging considerable, 45 cases of clattering glasses were reported, in 5 cases animals indoors became uneasy, small objects fell in 40 cases

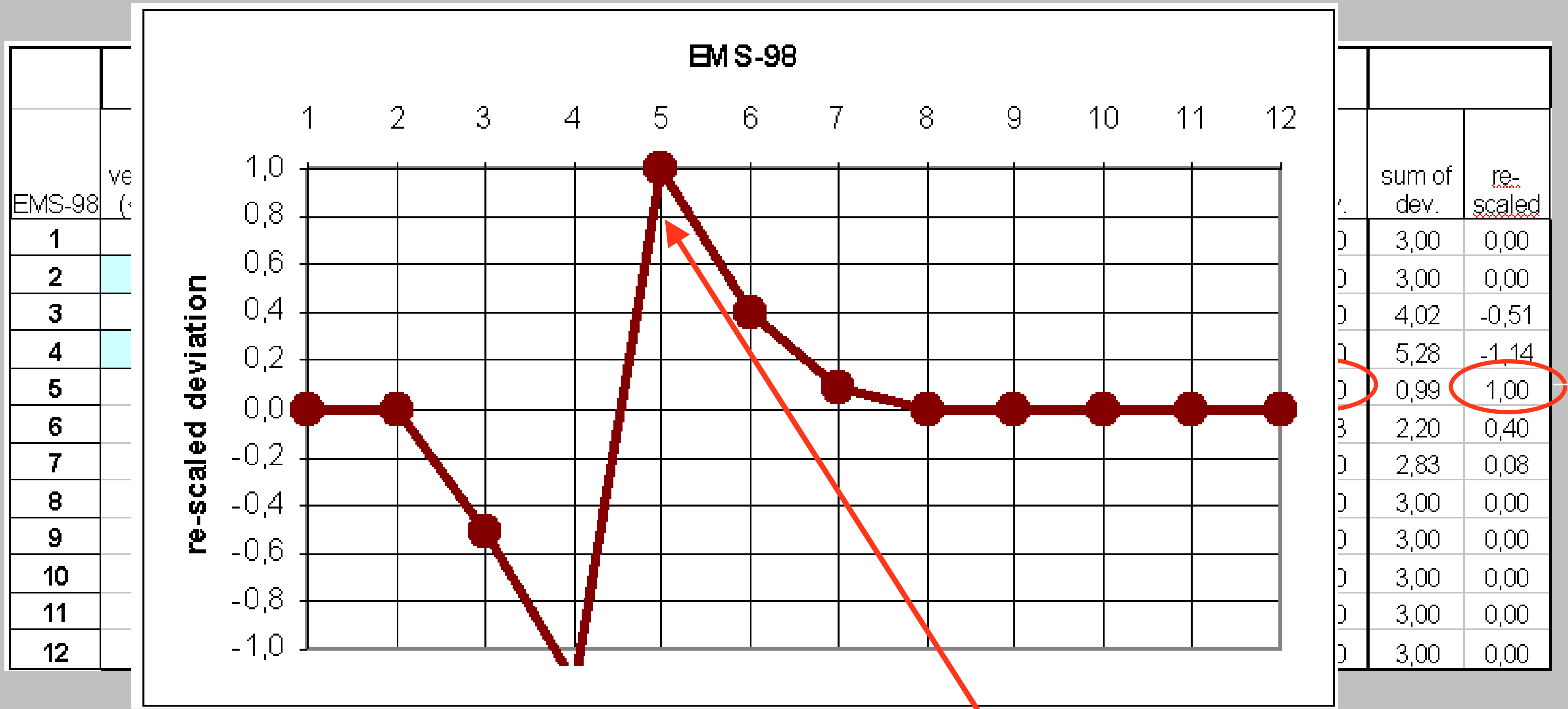
Building damage (vulnerability class, damage grade):
5 cases A damage 1, 5 cases B damage 1
Undamaged A = 45, B = 45

Position in Matrix	Human Perception
S = 90	Felt indoors
U = 40	Awaking
W = 10	Outdoors
X = 20	Frightened

Position in Matrix	Objects
K = (50, 45, 40, 5)$_{max}$	Lamps swing considerable, Glasses clatter, windows & doors open and shut, light top heavy objects shift or fall, animals indoors may become uneasy, liquids oscillate and may spill

Building type/ Damage	0	1	2	3	4	5
A	45	5				
B	45	5				
C						
D						
E						
F						

Example – Result



Resulting intensities:

Human Perception: 6
Objects: 5
Damage: 5

Overall intensity = 5

Note: The 'weighting-factors W1, W2 and W3' have been set to ‚1' for reasons of clarity.

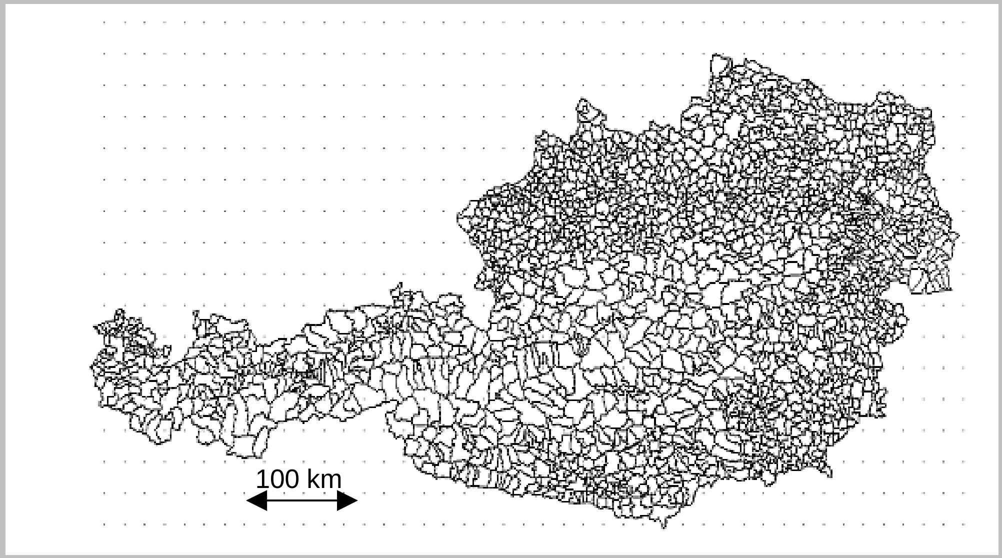
Intensity Map

For calculating ‘internet community intensities’, the ‚bin‘-size must be determined first.

Suggested bin-size:

Area of Austria divided by ZIP-districts (see below) = 83.000 km² / 2500 ZIP districts = 33 km², which equals an almost square bin with dimensions of approx. 5 km x 6 km grid or 1/12th of longitude times 1/20th of latitude.

Note: If the longitude/latitude grid is sub-divided by even integers, cross-border patching becomes possible.



Format for Data Exchange

Example of a format:

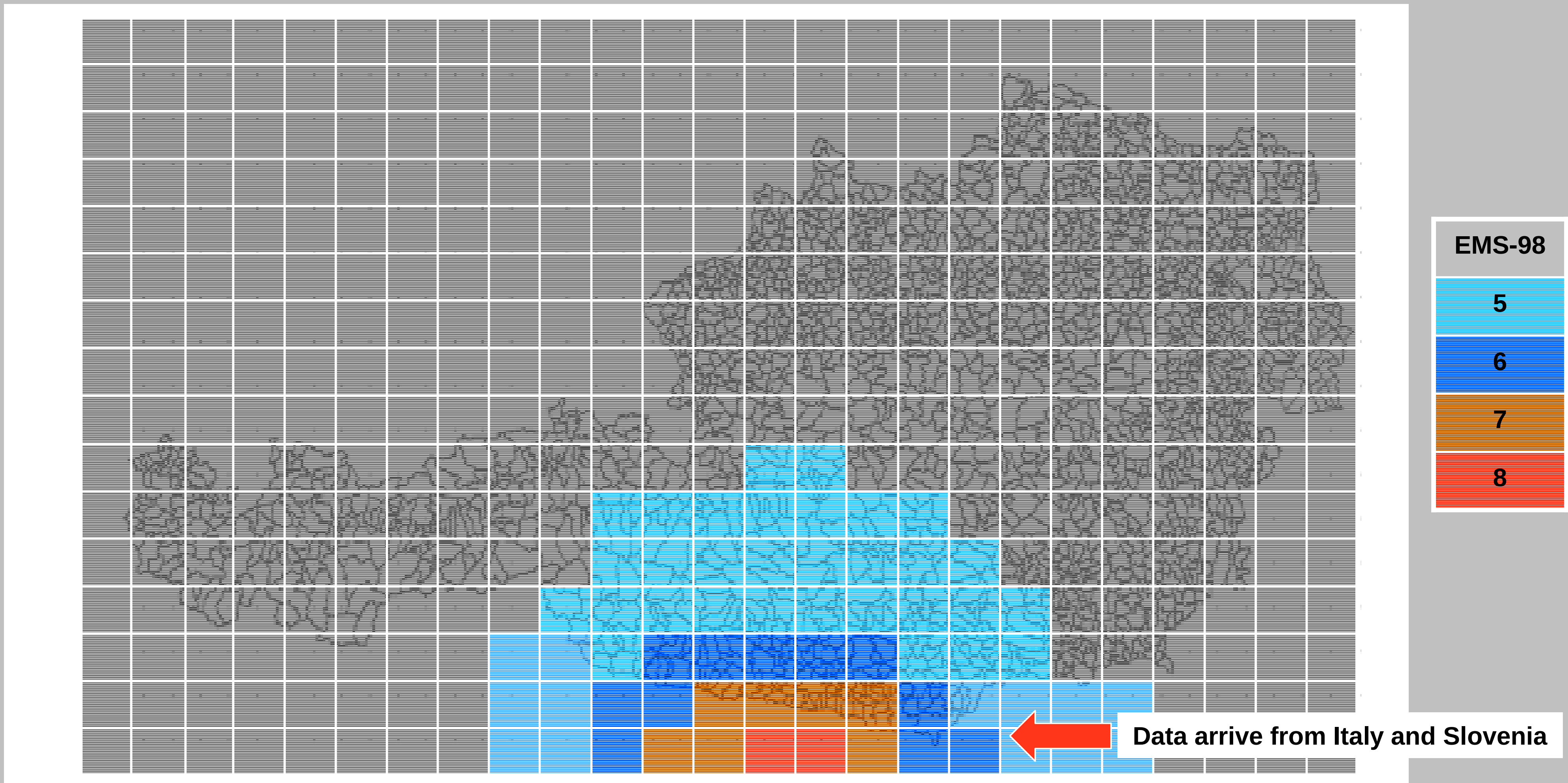
Header:
Date and time of earthquake, grid-size (X and Y) of bin = resolution of map

Followed by ‚n‘ rows stating:
Centre longitude, latitude, community-intensity of bin, intensity maximum, intensity minimum

```
20020214 1514 0.0833 0.0500
13.0417 46.0250 4 4 5
14.1250 47.0750 3 3 3
.
.
.
```

These data can be exchanged using either AutoDRM or by regular emails between partner institutions.

Cross-Border Patching



Example: not to scale!

Summary

Web-responses have surpassed mails/phone calls in Austria meanwhile.

The aim of this contribution is to ease the use of the EMS - discarding the fact the some communities (‚bins‘) are not ‚internet‘-prone. The method can also be applied to the study of historical earthquakes.

The approach aims at a

1. unified rapid efficient and objective evaluation procedure, and to
2. patch intensity-grid maps across political borders in almost real-time

once a format for exchanging these maps has been agreed upon.

Three categories were considered for each bin – or region:

1. Damage scenarios
2. Object scenarios
3. Human perception scenarios

Summary – cont‘d

- **Human Perception: Often no difference in the matrix positions between ‘running outdoors’, ‘felt outdoors’ (both scenario ‘W’) and ‘frightening’ (scenario ‘X’) can be observed. In such a case, the maximum of either ‘W’ or ‘X’ is entered in the matrix, if both occupy the same cell.**

- **Objects: The observation of <u>objects</u> is restricted to intensity degrees ranging from 3 to 8 according to the EMS-98. The observation of objects clearly dominates the end-result in the mid-range of intensities.**

- **Damage to Buildings: Most people don’t know the condition of their building, thus cannot report it, or give irrelevant answers. In such a case, vulnerability class ‘C’ is assumed in Austria.**
  The table linking building conditions to the quality of the building might need to be altered when used in other countries.
  Reports from high-rise buildings (above the 5th storey level, R* applies in Figure 1) are assigned a ‘community intensity’ of ‚2‘.

- **Effects in nature are discarded in the whole process, but kept in the data base and the seismologist is informed once such a message has been received via a questionnaire.**

Summary – cont‘d

- **Should two intensity rows show ‘similar’ re-scaled deviations, the intensity should be e.g. ‘5-6’, for it cannot be decided, whether degree ‘5’ or ‘6’ is more appropriate. As a proposal, ‘similar‘ could mean, that the ratio of the two dominating categories does not differ by more than a factor of 2/3.**
- **The seismologist should be able to access the data base at any time to correct/ complete the questionnaires.**
- **The method lends itself to study variations in quantities and their effect on intensity-assignments. This becomes apparent, when looking at the category ‘most’ in the ‘building-damage’-table. Completing the column down to intensity grade 7 (with e.g. A2, B1, and for intensity grade 8 with A3, B2, C1 and so on), would alter the intensity assignments drastically. In particular, many intensity 7-cases would then turn into intensity 8-cases, because the quantity ‘most’ is only addressed in the EMS-98 beyond intensity 9…**
- **The presented method should only be used, when all three categories can be considered.**

Although the presented approach seems complicated, it is relatively easy to compute by setting pointers to the appropriate cells of tables in a database thus assessing the ‚community intensity‘ most objectively.

Epilogue

- **The method doesn‘t work beyond intensities of 5, once building damages are considered.**

- **Questionnaires were and are still subject to modifications, and they are not consistent – when compared between different countries.**

- **Solution:**
  Investigate the national questionnaires in terms of relevance for the EMS-98.
  Allow only one confirmation for a particular effect.
  The presented tables need to be modified – beyond the EMS-98. That is to include not mentioned effects. This approach stabilizes fundamentally the automatic evaluation of intensities.