HELMHOLTZ CENTRE POTSDAM
GFZ GERMAN RESEARCH CENTRE FOR GEOSCIENCES

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Seismic Risk Assessment for Earthquake Early Warning and Rapid Response Systems: the Bishkek (Kyrgyzstan) test case

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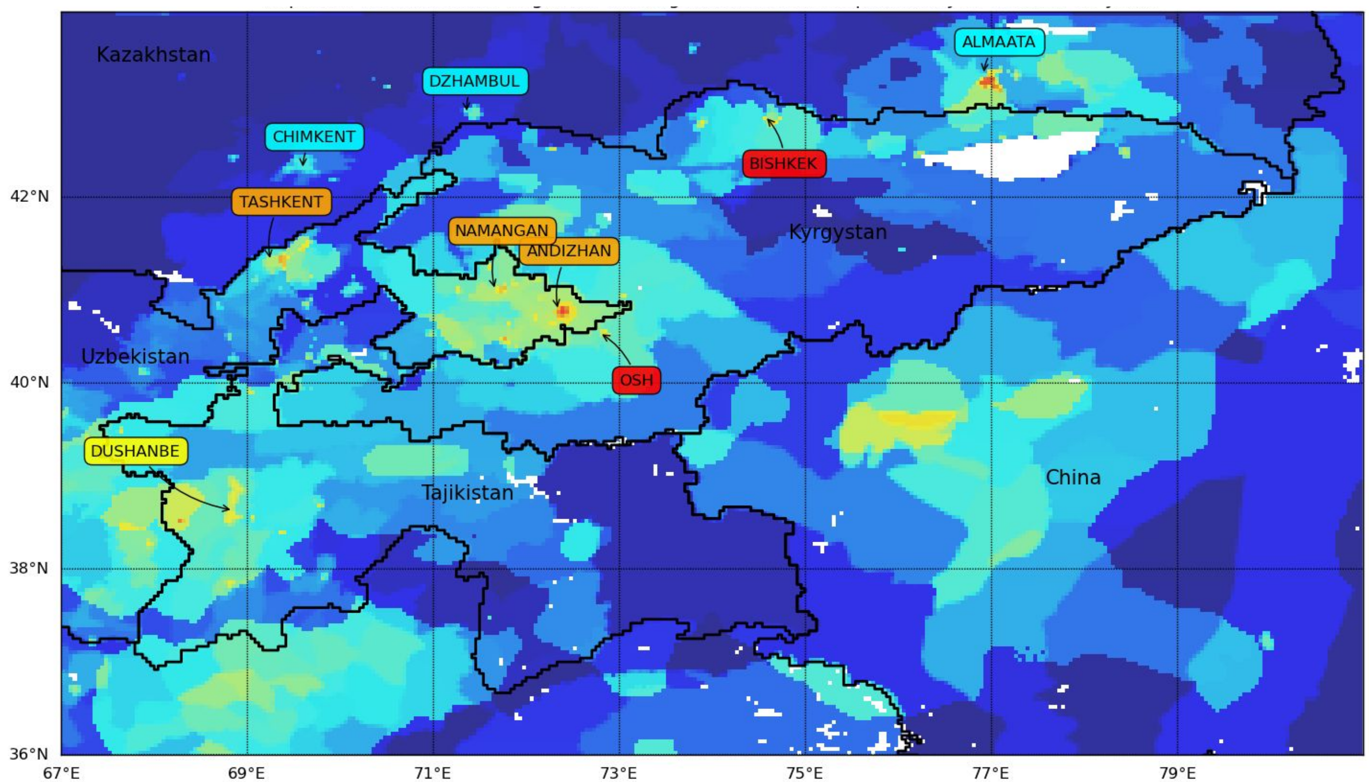
GFZ Potsdam, Sect. 2.1 - Seismic Risk and Early Warning,
GFZ Potsdam - Centre for Early Warning

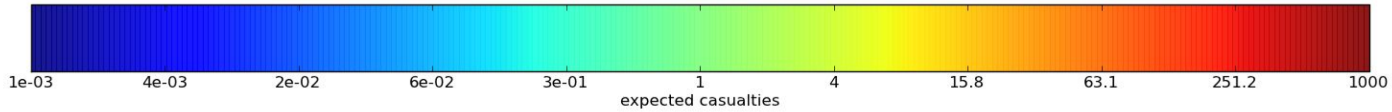
Summary

- Earthquake Early Warning (EEW) systems in Central Asia
- Overall design
- Risk Assessment for EEW Systems, test case: Bishkek
- Scenario design and earthquake simulation
- Risk Assessment for considered scenario
- Conclusions

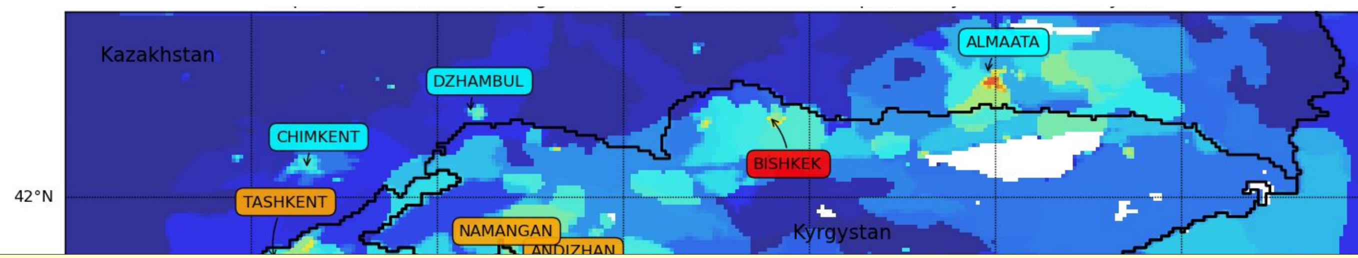
Earthquake Early Warning (EEW) systems in Central Asia



Distribution of expected casualties – hazard with exc. prob. 10% in 50 yrs

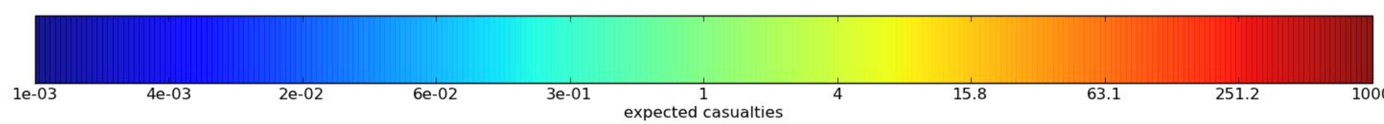


Earthquake Early Warning (EEW) systems in Central Asia

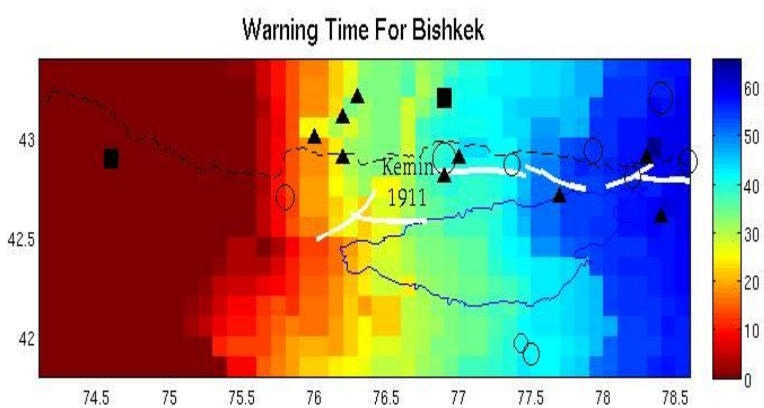


Desired Requirements

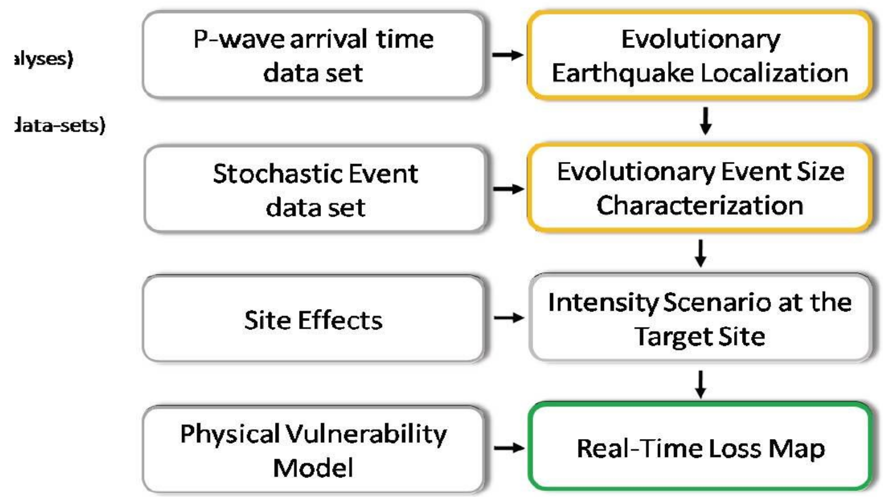
- two use-scenarios:
  regional - pre-event measures, risk mitigation
  local - search & rescue optimization, disaster management
- **target-driven**, focused approach
- **optimization** of sensors network
- fast, reliable **event characterization**
- spatially detailed**,** uncertainty-aware **risk assesment**, with efficient **management** of (*lack of*) **information**

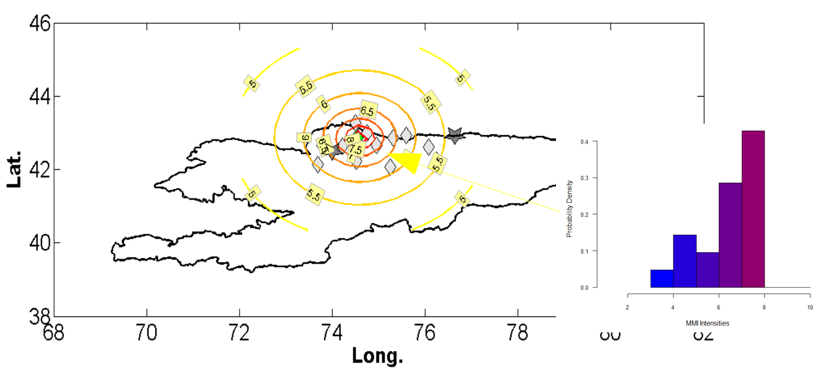


EEW Systems in Central Asia: proposed design

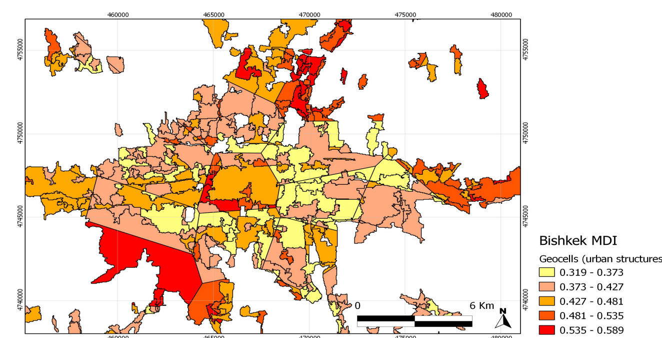


Optimized placement of e.w. seismic stations (e.g. Bishkek - Almaty)





Intensity scenario at target site (e.g. Bishkek)

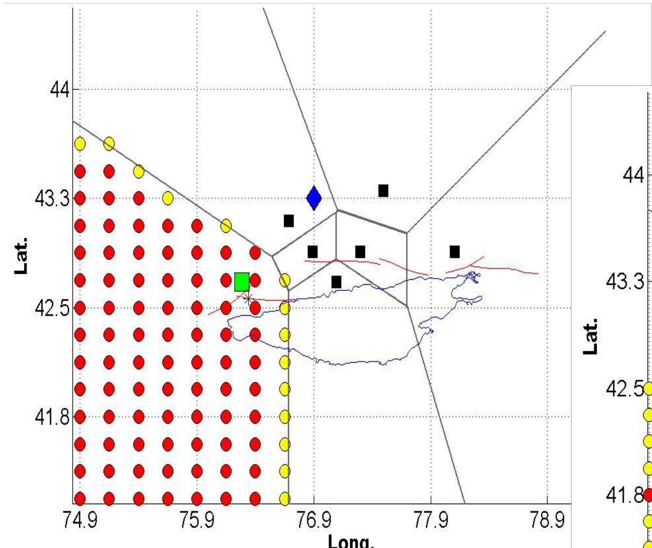


Real-time Damage/Loss Map (e.g. Bishkek)

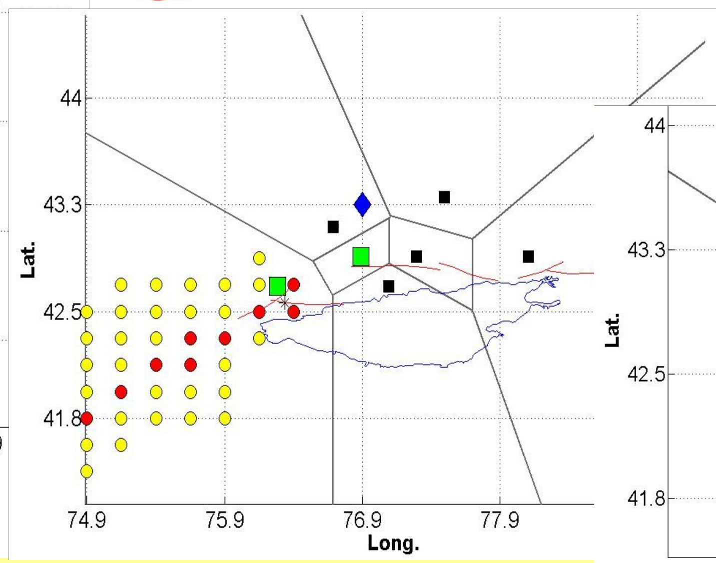
Evolutionary Event Characterization

time

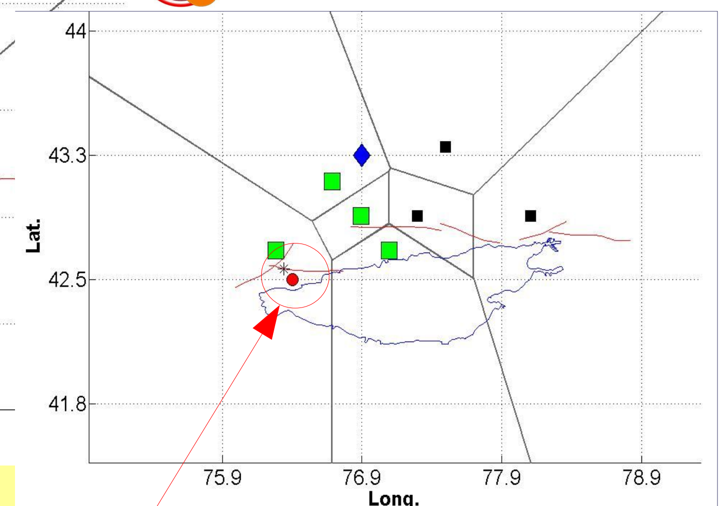
Lead Time: 22 sec



Lead Time: 17 sec



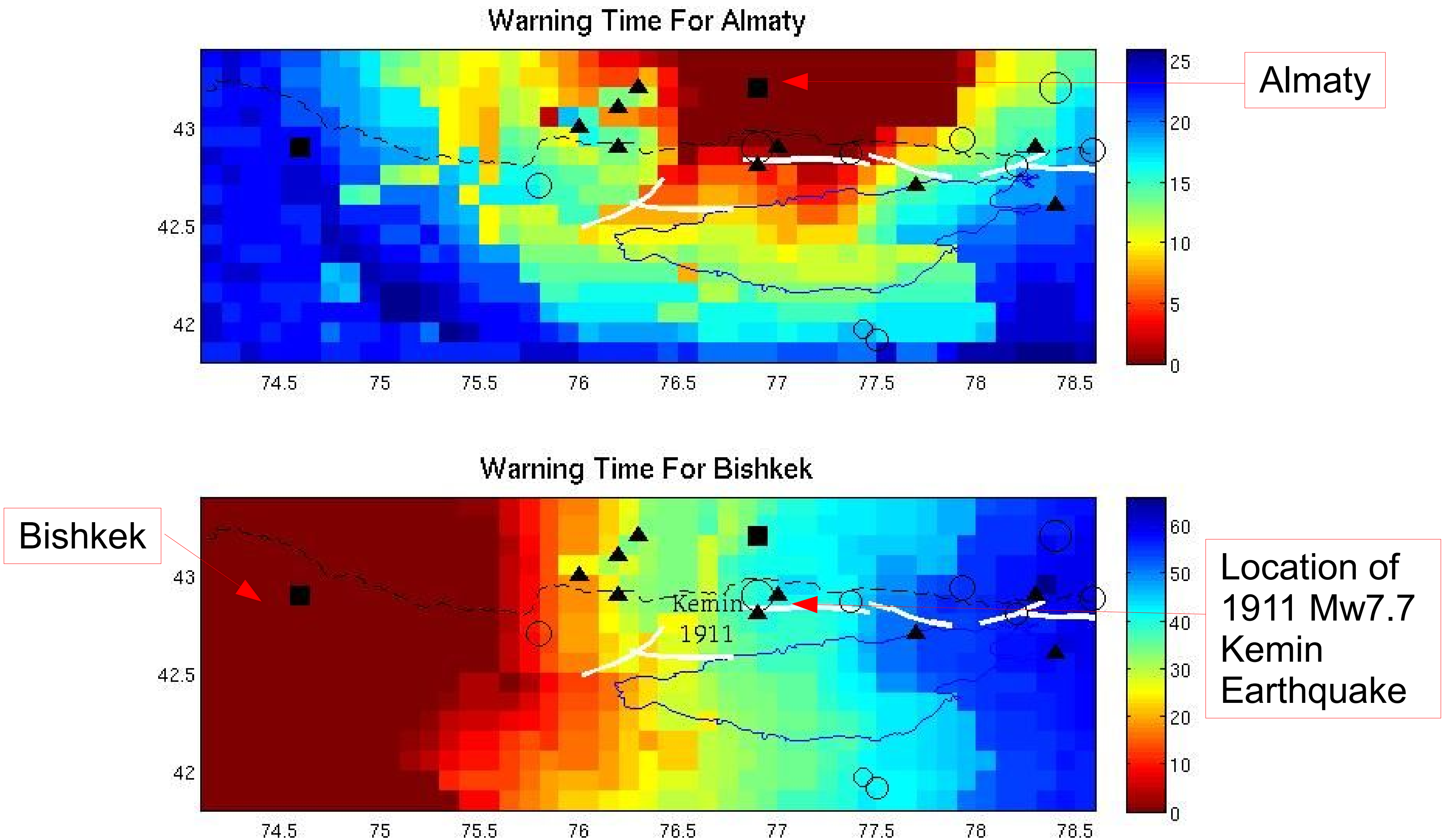
Lead Time: 14 sec



Real-time filtering of damage and loss scenarios

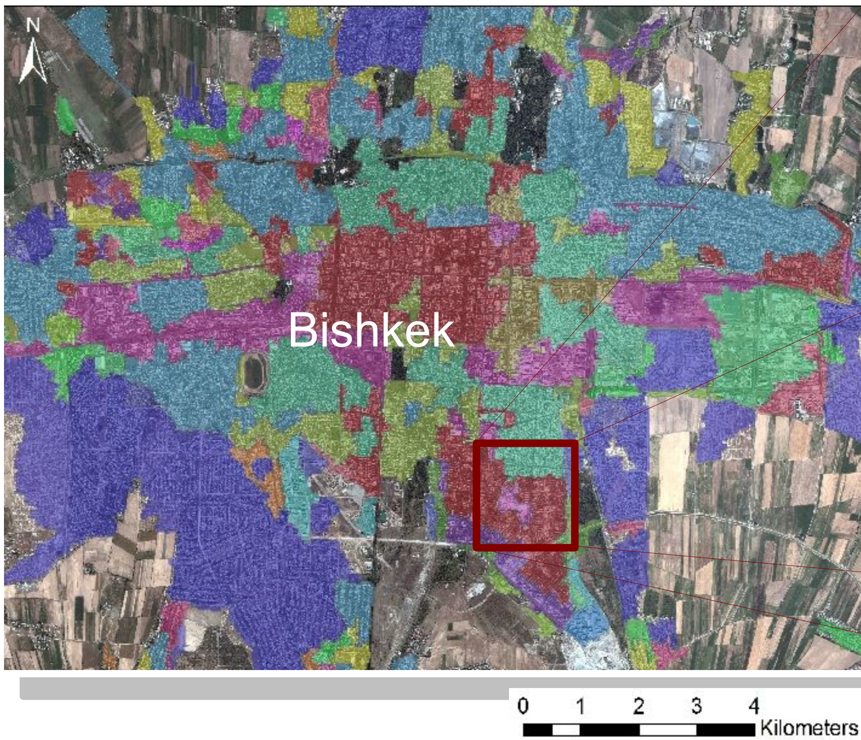
Event characterized, most probable scenario selected. Broadcast warning

Regional Network Optimization



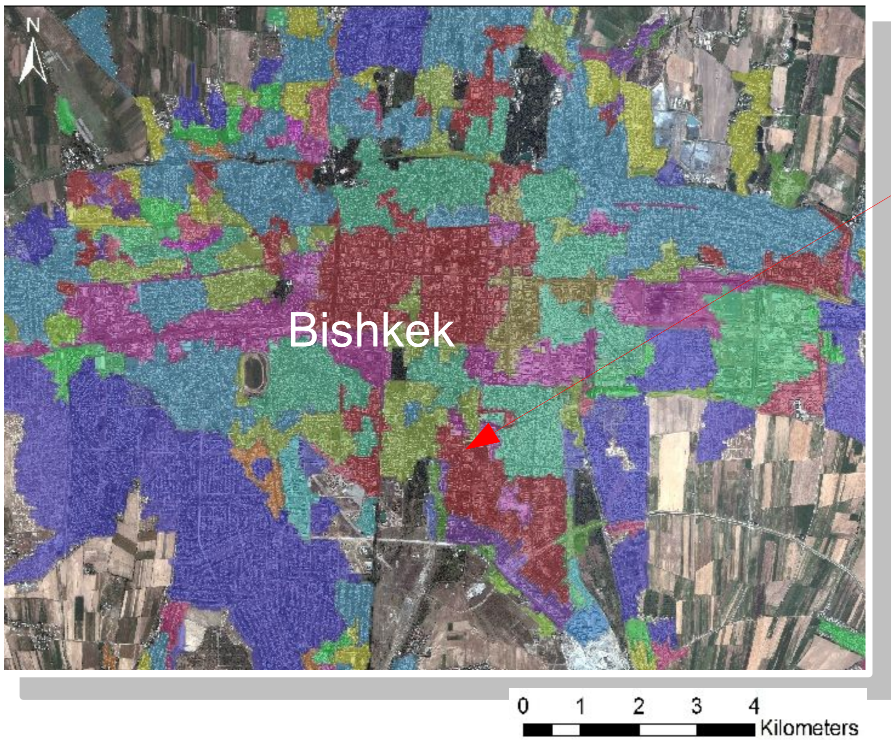
Multi-source, multi-scale exposure and vulnerability assessment

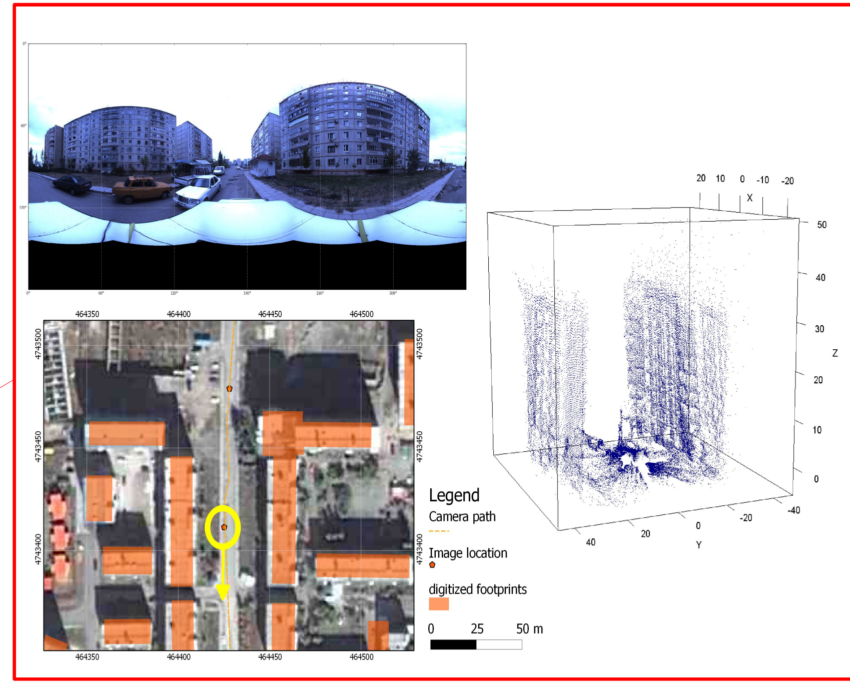
Stratification based on Analysis of MR satellite images



Multi-source, multi-scale exposure and vulnerability assessment

Stratified sampling

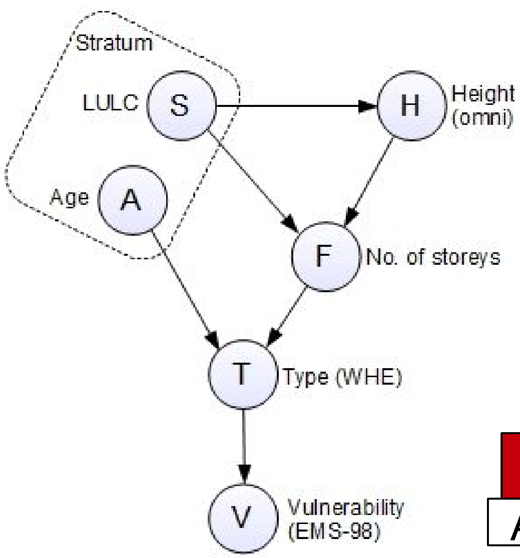




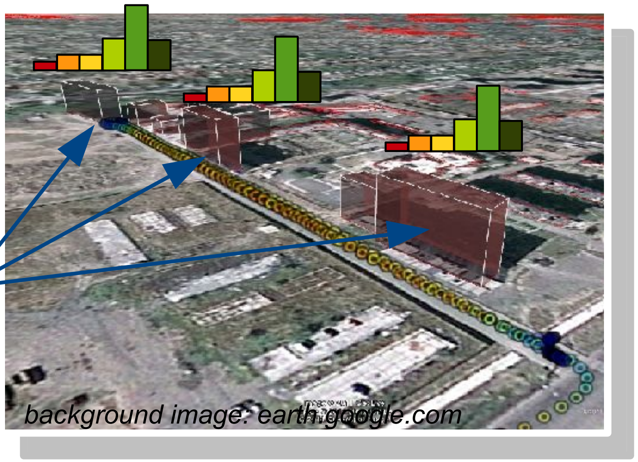
Ground-based sampling based on Rapid Visual Screening (RVS) and Omnidirectional Imaging

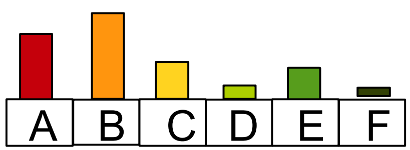
Probabilistic data integration for Vulnerability and Risk assessment

Bayesian networks



Age: 1994-2009
Height: 29 m
No. of storeys: 9
WHE Type: 6
Vuln. (EMS-98): E

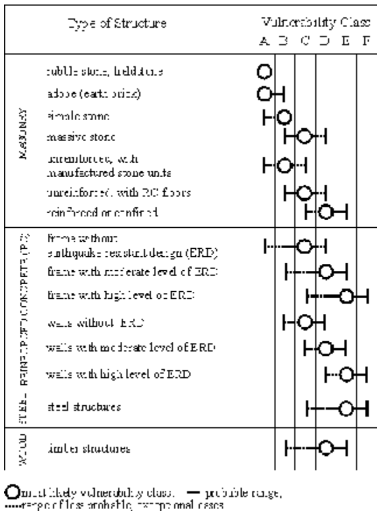




posterior probability

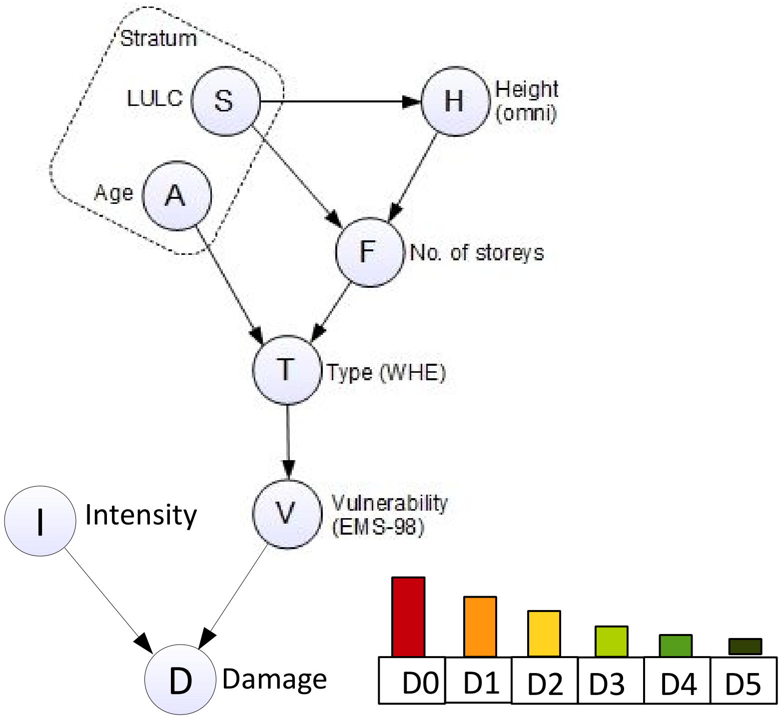
type	P(A)	P(B)	P(C)	P(D)	P(E)	P(F)
0	0.9334	0.04757	0.01903	0	0	0
1	0.175	0.56706	0.19842	0.01984	0.01984	0.01984
2	0.175	0.56706	0.19842	0.01984	0.01984	0.01984
3	0.175	0.56706	0.19842	0.01984	0.01984	0.01984
4	0.0181	0.215	0.427	0.2964	0.0435	0
5	0.0181	0.215	0.427	0.2964	0.0435	0
6	0	0.0303	0.06061	0.22	0.43911	0.24998
7	0	0.0303	0.06061	0.22	0.43911	0.24998

conditional probability table (V)

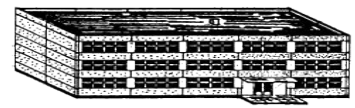
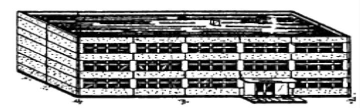
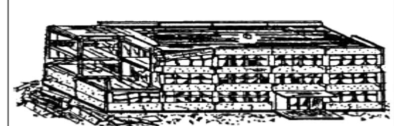


Probabilistic data integration for Vulnerability and Risk assessment

Bayesian networks



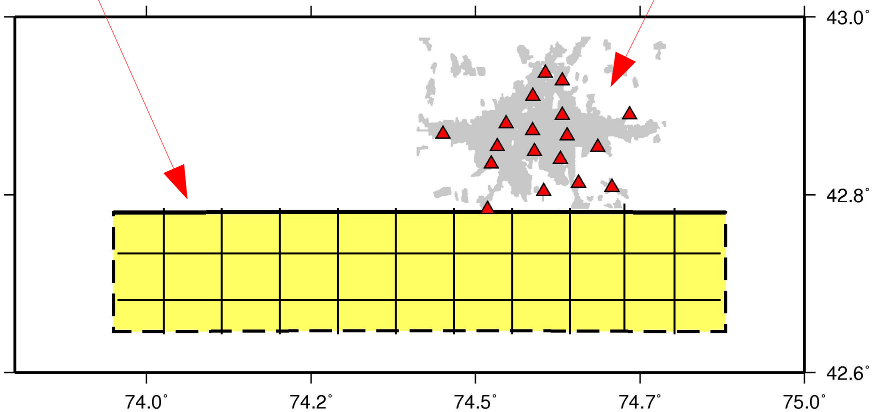
EMS-98 Damage
posterior probability

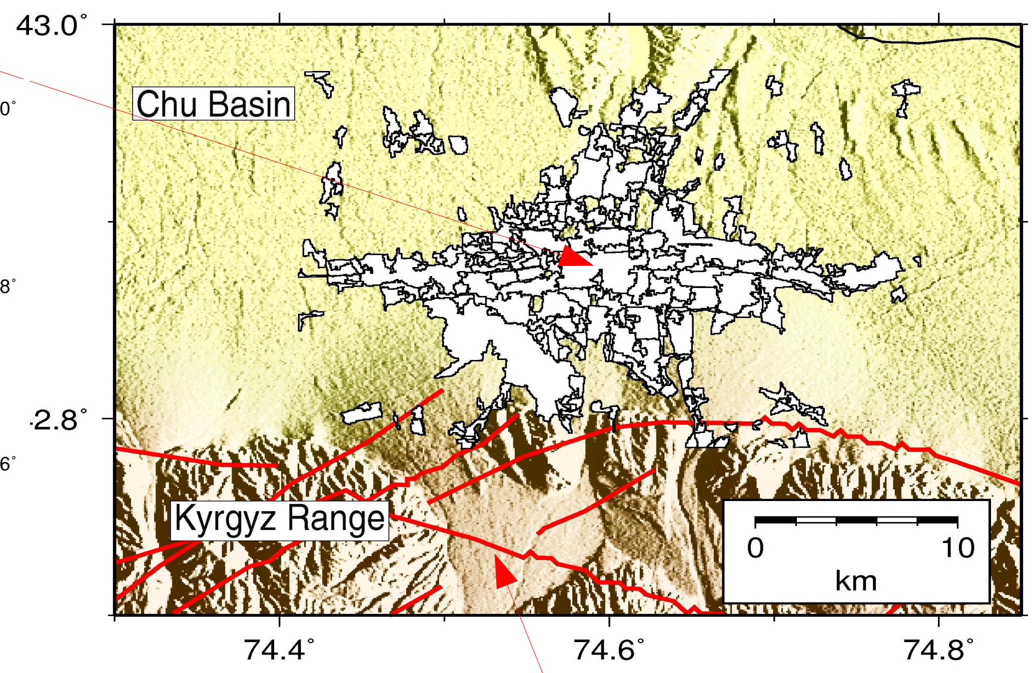
Classification of damage to buildings of reinforced concrete	
	**Grade 1: Negligible to slight damage** **(no structural damage, slight non-structural damage)** Fine cracks in plaster over frame members or in walls at the base. Fine cracks in partitions and infills.
	**Grade 2: Moderate damage** **(slight structural damage, moderate non-structural damage)** Cracks in columns and beams of frames and in structural walls. Cracks in partition and infill walls; fall of brittle cladding and plaster. Falling mortar from the joints of wall panels.
	**Grade 3: Substantial to heavy damage** **(moderate structural damage, heavy non-structural damage)** Cracks in columns and beam column joints of frames at the base and at joints of coupled walls. Spalling of conrete cover, buckling of reinforced rods. Large cracks in partition and infill walls, failure of individual infill panels.
	**Grade 4: Very heavy damage** **(heavy structural damage, very heavy non-structural damage)** Large cracks in structural elements with compression failure of concrete and fracture of rebars; bond failure of beam reinforced bars; tilting of columns. Collapse of a few columns or of a single upper floor.
	**Grade 5: Destruction** **(very heavy structural damage)** Collapse of ground floor or parts (e. g. wings) of buildings.

Earthquake Scenario considered test case

Modelled fault

Bishkek





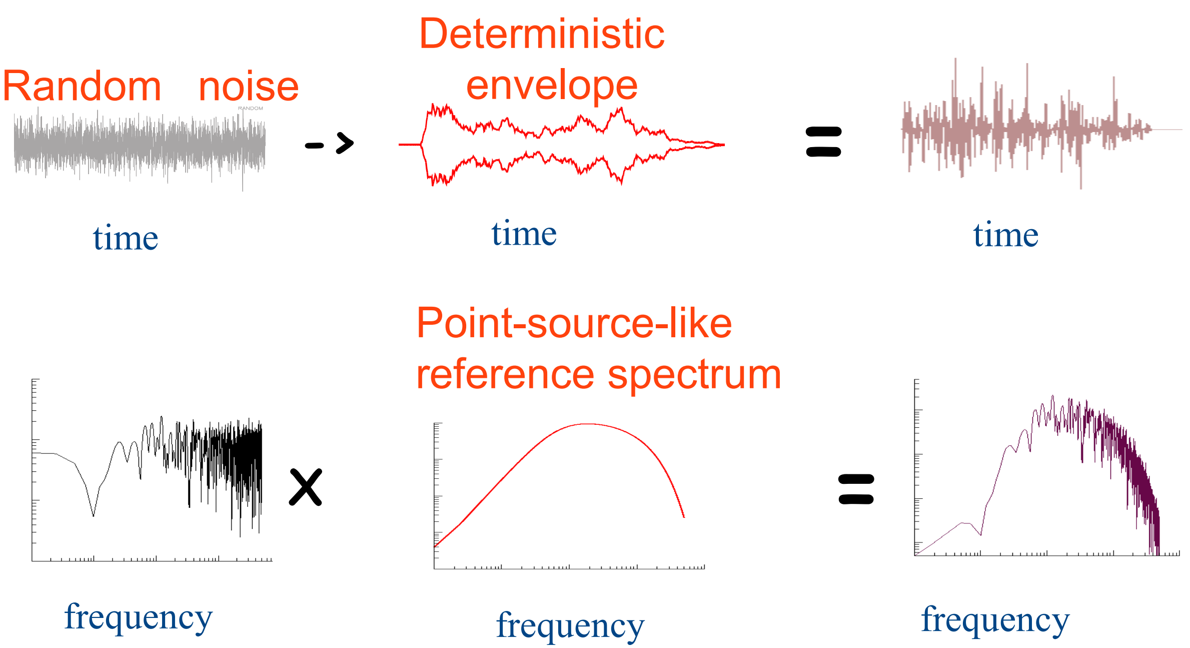
Issyk-Ata faults system

- Strike: East-west dip=50°
  reverse mechanism

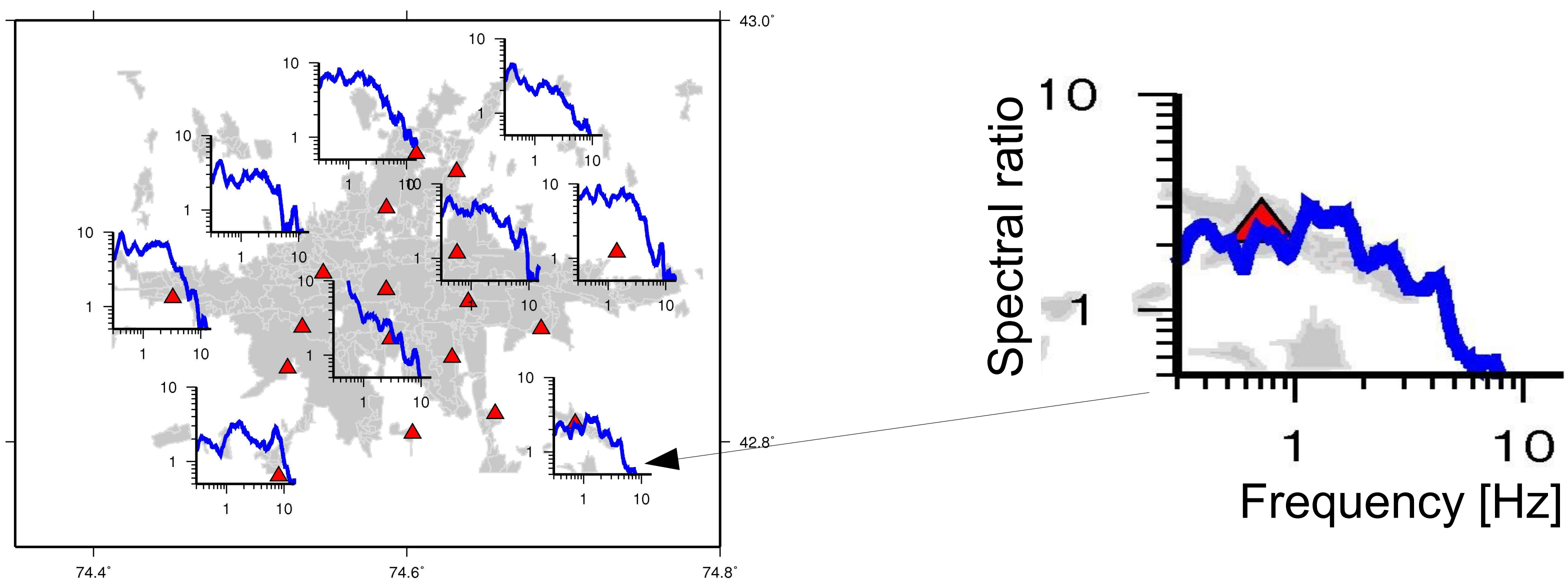
- Two scenarios, **M=7** and M=7.5 with stress drop varying from 2 to 200 bars.

Earthquake Scenario Simulation Scheme

Stochastic simulation using **EXSIM** (**Motazedian and Atkinson 2005**). Point-source contributions from each sub-fault are summed at observation sites with proper time delays.

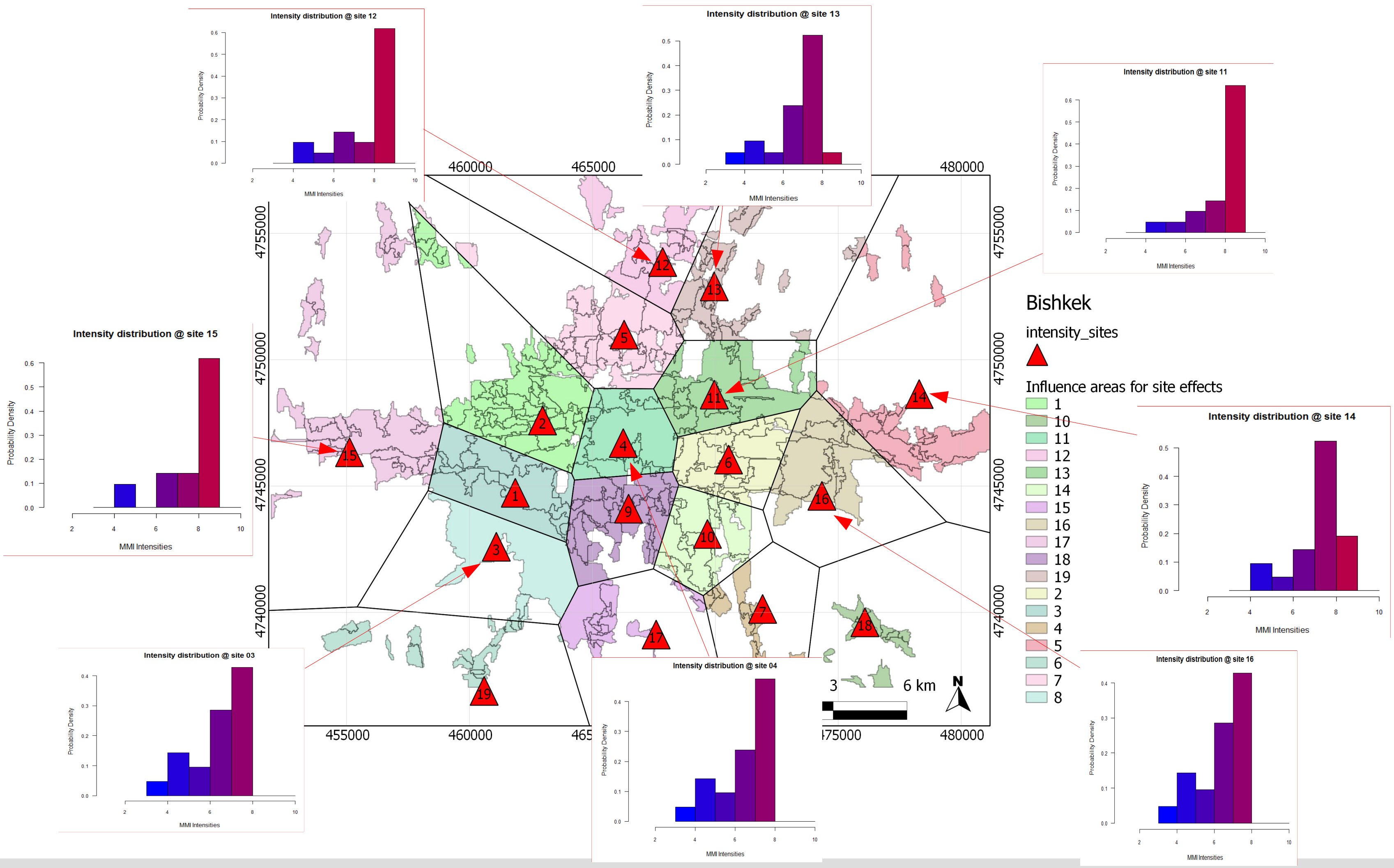


Earthquake Scenario
Site Effects Correction



Empirical estimates of site effects available at 19 sites (Parolai et al 2010) are convolved with simulated spectra and transformed to MSK-intensity following the study of Sokolok and Chernov (1998) on the correlation between Fourier amplitude spectra of acceleration and intensity. **For each site, a distribution of intensities is computed** (related to the variability of stress drop introduced in the simulations)

Earthquake Scenario M7
Spatial Distribution of Simulated Intensity



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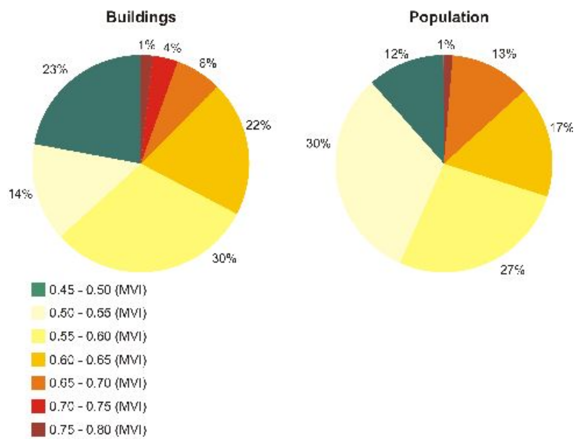
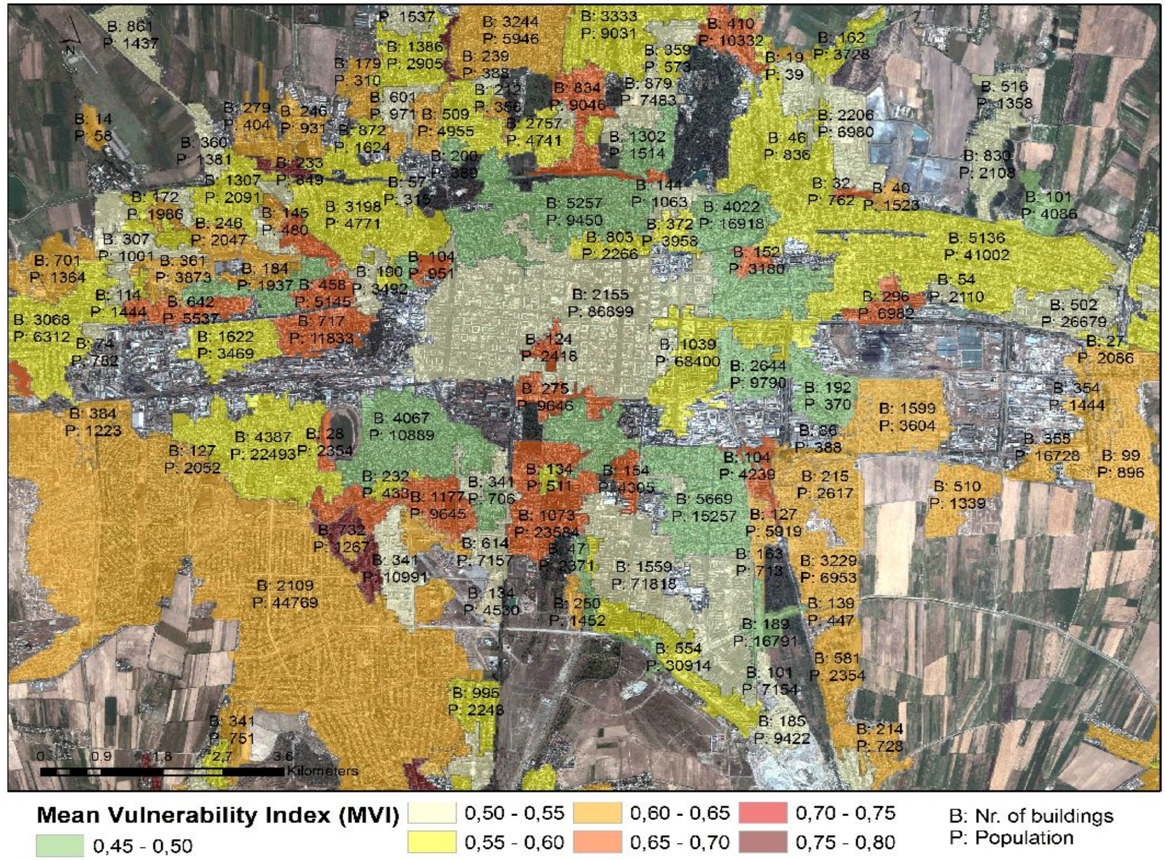
Bishkek - Vulnerability Model



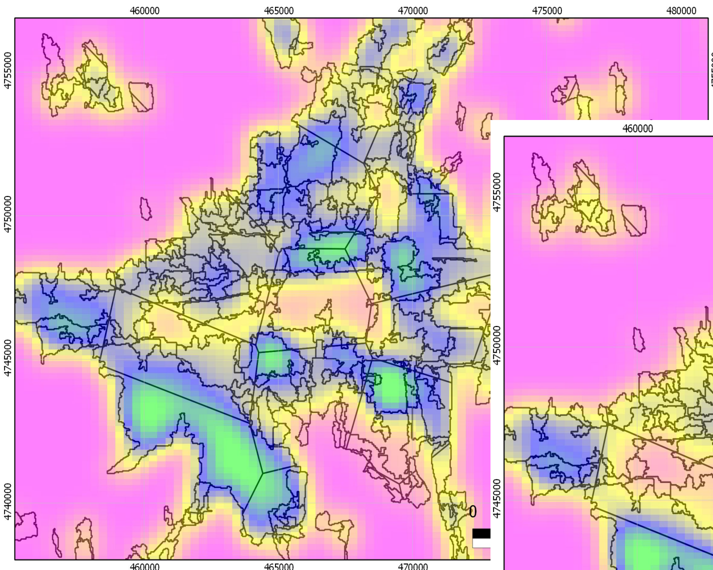


Mean Vulnerability Index (MVI)	Est. nr. of buildings	Est. population
0.45-0.50	25582	99969
0.50-0.55	15722	266175
0.55-0.60	34377	227410
0.60-065	24322	140810
0.65-0.70	6606	110130
0.70-0.75	4177	0
0.75-0.80	1507	3145
TOTAL	**112293**	**847639**

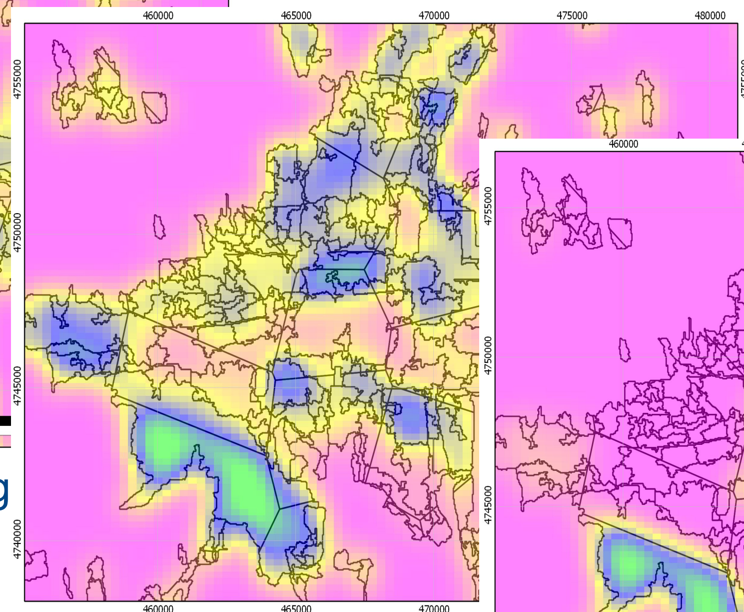
$$MVI=\frac{1}{(n-1)}\left(\sum_{i=0\ldots n-1} p(V_i)(n-i)-1\right)$$

Building spatial densities have been Estimated by fitting a 2D Poisson Point Process to a training set of building footprints

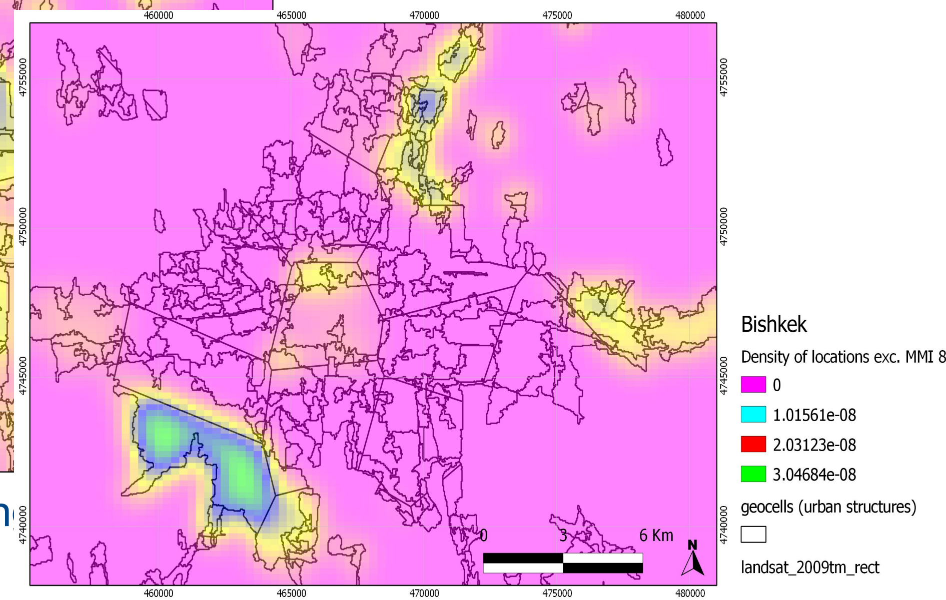
Earthquake Scenario
Macroseismic Intensity vs. Building Density



Spatial density of buiding
exposed to MSK I ≥ 6



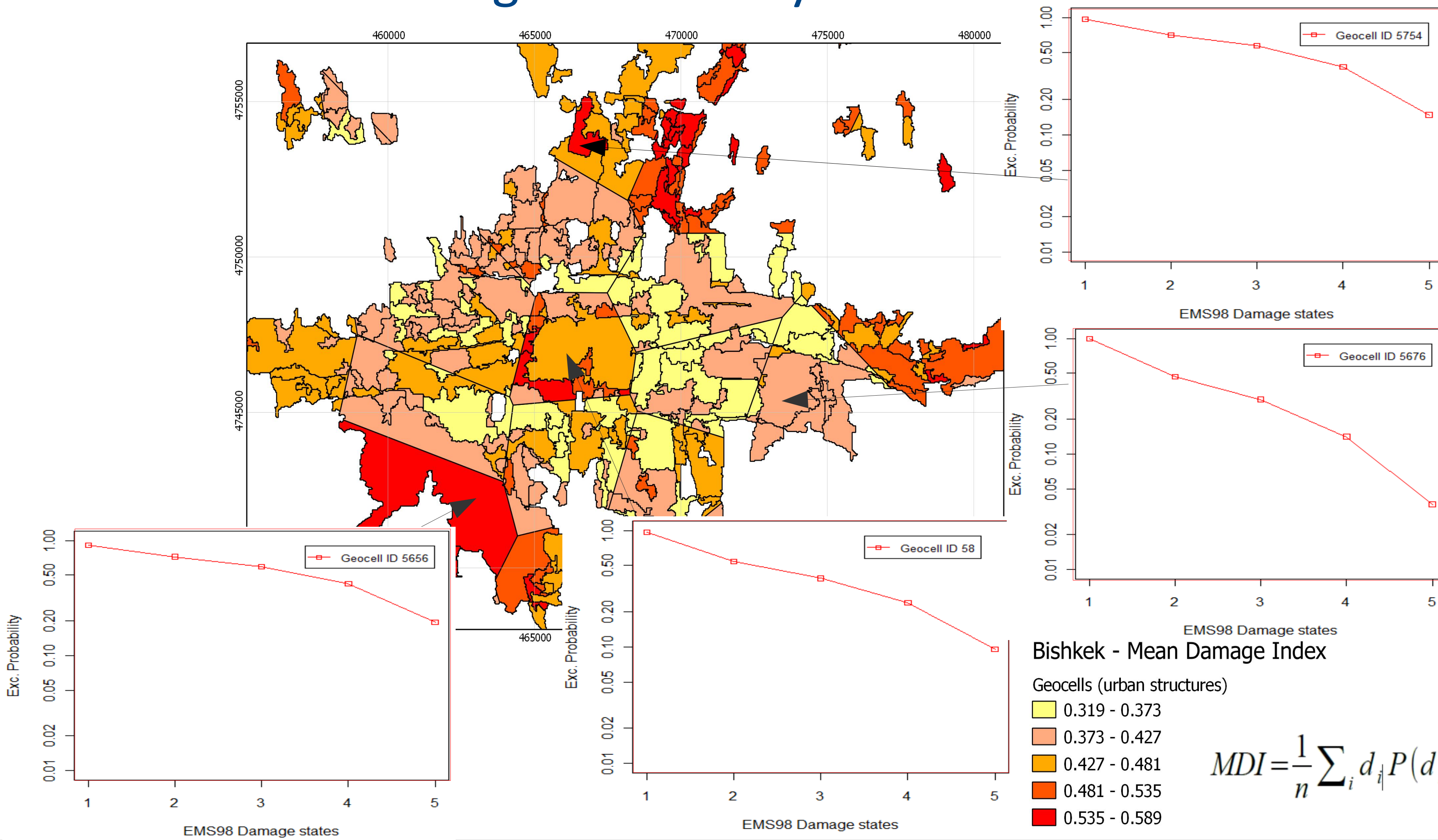
Spatial density of buidin
exposed to MSK I ≥ 7



Spatial density of buidings
exposed to MSK I ≥ 8

Building distributions estimated
by averaging stochastic realizations of
2D Poisson Point Process in any geocell

Earthquake Scenario
Damage Probability of Exceedance



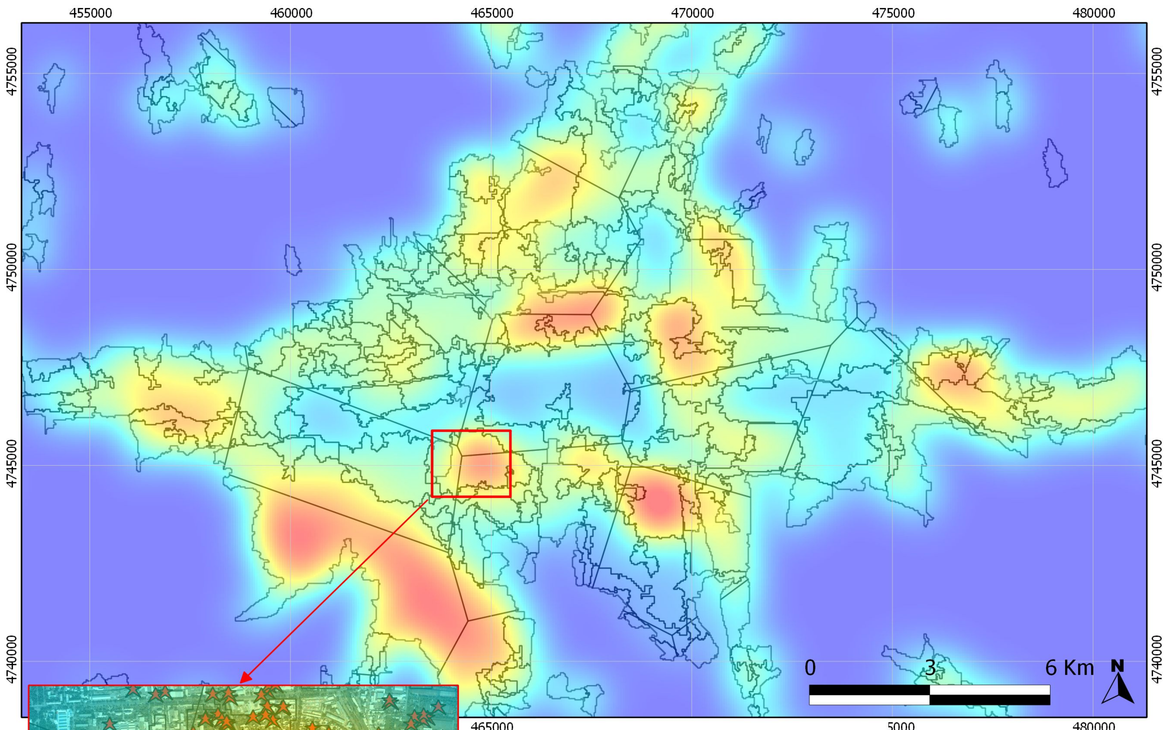
Bishkek - Mean Damage Index

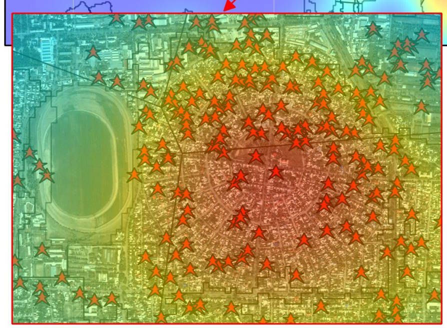
Geocells (urban structures)

- 0.319 - 0.373
- 0.373 - 0.427
- 0.427 - 0.481
- 0.481 - 0.535
- 0.535 - 0.589

$$MDI = \frac{1}{n} \sum_i d_i P(d_i)$$

Earthquake Scenario
Expected Spatial Density of Collapses





Close-up - Hyppodrome - simulated collapses

Bishkek

spatial density of collapses (1/sqm)

- 3e-6
- 1.1e-5
- 2e-4
- 2.2e-04

Estimated Building collapses: ~13000

Conclusions

- *Evolutionary Event Characterization* and *network optimization* show a great potential in application to Earthquake Early Warning (EEW) Systems.

- Next´s generation EEW Systems need *reliable, spatially detailed* and *up-to-date* Risk Assessment.

- Several Risk Scenarios for Bishkek are under assessment, with uncertainty modelling and high spatial disaggregation. Preliminary results are very encouraging.

- Careful *data collection and integration* and new technologies will be further explored in a *multiple-scale*, *holistic* framework.

Thank you!

Спасибо!

EEW network optmization Via Genetic Algorithm