



Preparation of input data: catalogue Krško NPP case study

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Task

Earthquake catalogue:

- **Regional (150 km)**
for seismic hazard study
- **Near regional (25 km)**
for seismotectonic model



Catalogue sources (1/3)

- - Catalogue of earthquakes in Slovenia (Ribarič, 1982), contains all earthquakes till 1981 within the political boundaries of Slovenia;
- - Earthquake catalogue for Croatia and neighbouring regions (Cvijanović, 1981), contains earthquakes with $l_o \geq VII$ MCS till 1900 and $M \geq 4.0$ or $l_o > V$ MCS from 1901 to 1970 within Croatia and numerous stronger earthquakes in the neighbouring regions;
- - Earthquake catalogue for Croatia and neighbouring regions (Herak et al., 1996), contains earthquakes with $M \geq 3.5$ or $l_o \geq V$ MCS till 1999 within Croatia the neighbouring regions;



Catalogue sources(2/3)

- - Catalogue of earthquakes in Yugoslavia 1971-1985 (Skoko et al., 1989), contains earthquakes with $M \geq 4.0$ within the political boundaries of former Yugoslavia;
- - Catalogue of earthquakes in European area (Karník, 1968 in 1971), contains earthquakes with $Io \geq VII$ MCS from 1801 to 1900, and $Io \geq VI$ MS or $M \geq 4.5$ from 1901 to 1955 in Europe;
- - Catalogue of earthquakes in Balkan Region (Shebalin et al. Eds., 1974), contains, among the others, earthquakes with $Io \geq VIII$ MCS till 1800, $Io \geq VII$ MCS till 1900 and $Io \geq VI$ MSK or $M \geq 4.0$ from 1901 to 1970 for the former Yugoslavia;



Catalogue sources(3/3)

- - Catalogue of earthquakes for the region of Eastern Alps (OGS, 1992), contains all earthquakes till 1984 for the area between 45° and 47° N and between 12° and 16° E;
- - Catalogue of earthquakes in Hungary (Zsíros et al., 1988), contains all earthquakes till 1991 in Hungary and numerous in the neighbouring countries;
- - Catalogue of earthquakes in Austria (ZAMG, 2002), contains earthquakes with $l_o \geq III$ MSK within the political boundaries of Austria.



Major input catalogues

| Catalogue | Start | End | Imin | Mmin | M |
|-------------------------------|----------------------|----------------------|----------------------------------|------|----------------------------|
| Ribarič, 1982 | -999 | 1981 | II MSK-64 | | macroseismic |
| Cvijanović, 1981 | -999 1901 | 1900 1970 | VII MCS V MCS | 4,0 | macroseismic MLH, ML |
| Herak et al., 1996 | | 1999 | V MCS | 3,5 | ML, other |
| Skoko et al., 1989 | 1971 | 1985 | | 4,0 | MLH, mb, ML |
| Karník, 1971 Karník, 1968 | 1801 1901 | 1900 1955 | VII MS VI MS | 4,5 | macroseismic mostly MLH |
| Shebalin et al. Eds., 1974 | -999 1801 1901 | 1800 1900 1970 | VIII MCS VII MCS VI MSK-64 | 4,0 | macroseismic mostly MLH |
| OGS, 1992 | -999 | 1984 | | | macroseismic MD, Mwa |
| Zsíros et al., 1988 | -999 | 1987 | | | ? |
| ZAMG, 2002 | 1200 | 2002 | III | | macroseismic |



Input magnitudes statistics

Ribarič, 1982:

- MS (MLH) 35
- mb 8
- ML 76
- Mm 2565



Unified catalogue

Sovereignty principle:

The best estimate of earthquake parameters is by the authority from the country where the earthquake is located.

Works fine but sometimes leads to double events or earthquakes that no one wants.



Unified catalogue

| Year | MM | DD | hh | mm | sec | Lat. | Long. | Depth | MS | mb | ML | Mc | Mm | Io | Mu | e | h | m | M | Ref. |
|------|----|----|----|----|------|-------|-------|-------|-----|-----|-----|-----|-----|------|-----|---|---|---|---|-------|
| 1511 | 3 | 26 | 14 | 0 | 0.0 | 46.10 | 14.00 | 15.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.8 | 10.0 | 6.8 | G | E | C | C | EGS98 |
| 1917 | 1 | 29 | 8 | 22 | 55.0 | 45.90 | 15.57 | 13.2 | 5.7 | 0.0 | 0.0 | 0.0 | 5.4 | 8.0 | 5.7 | D | D | C | C | VR1 |
| 1998 | 4 | 12 | 10 | 55 | 32.3 | 46.31 | 13.63 | 7.6 | 5.7 | 5.3 | 5.6 | 0.0 | 5.3 | 7.5 | 5.7 | B | B | A | A | LJU98 |



Unified magnitude

Unified magnitude rule:

- $M_u = MS$ if MS known, if not
- $M_u = ML$ if ML known, if not
- $M_u = 1.76mb - 3.60$ (Ambraseys, 1990 for European area, $3 < M < 8$) if mb known, if not
- $M_u = Mm$ if Mm known, if not
- $M_u = 0.494I_o + 1.27\log(\text{depth}) + 0.09$ (Zivcic, 1992 for the "NPP Krsko PSHA catalogue")
- if unknown depth assumed to be 8 km

Mu from:

| | |
|----------------|-----|
| MS | 68 |
| ML | 110 |
| Mb | 21 |
| Mm | 611 |
| I _o | 340 |



Earthquake catalogue for regional area

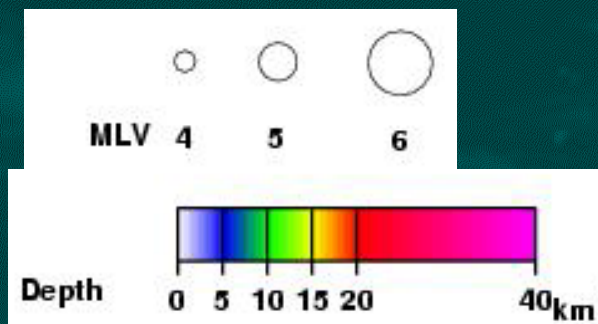
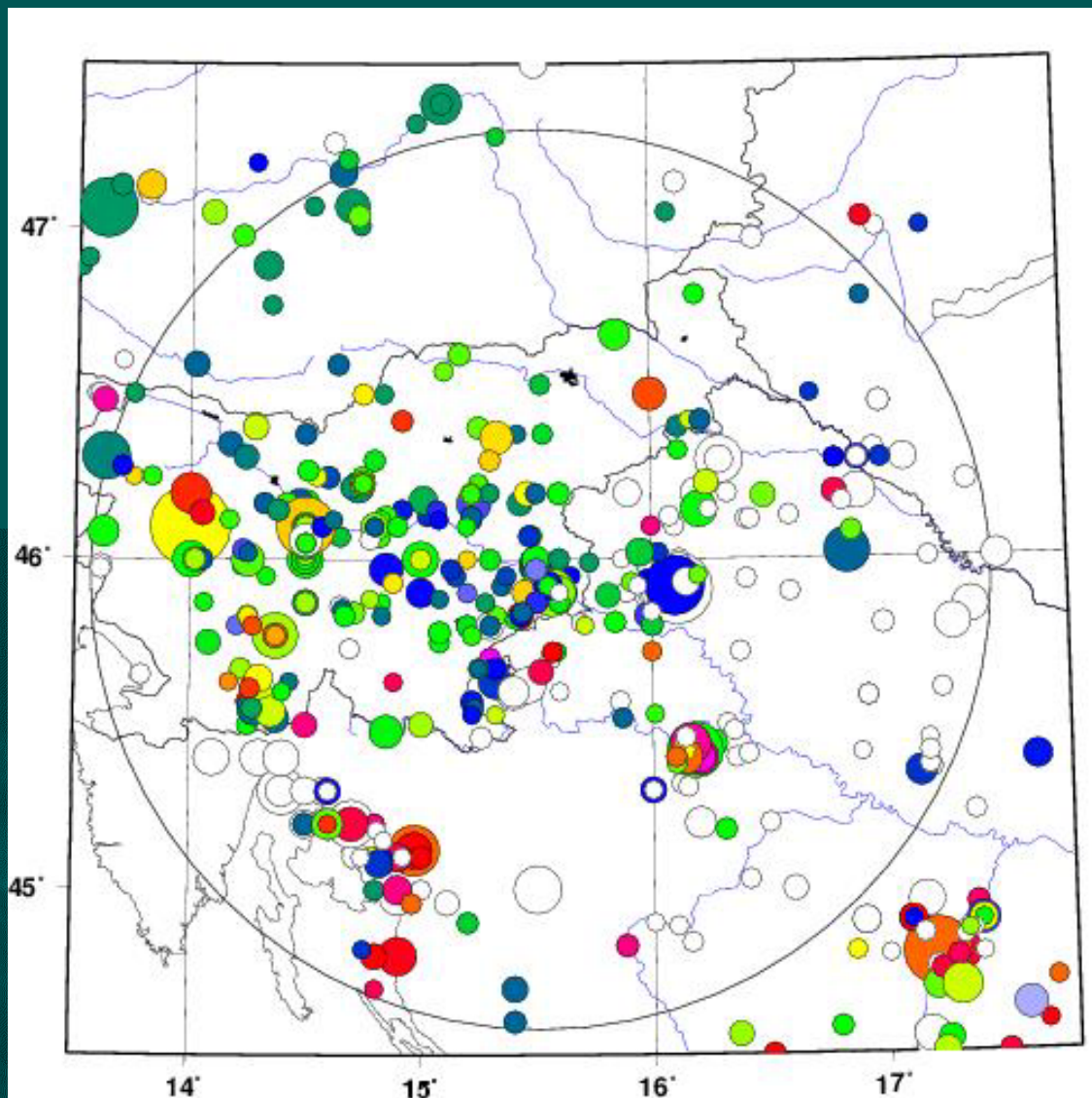
- Period from 567 to 2001
- Parametres mostly from macroseismic data
- Location accuracy ± 20 to 50 km
- Unified magnitudes: M_{LH} from isoseismal radii and maximum intensities
- 1150 earthquakes with $M \geq 3.5$



Earthquakes in regional area

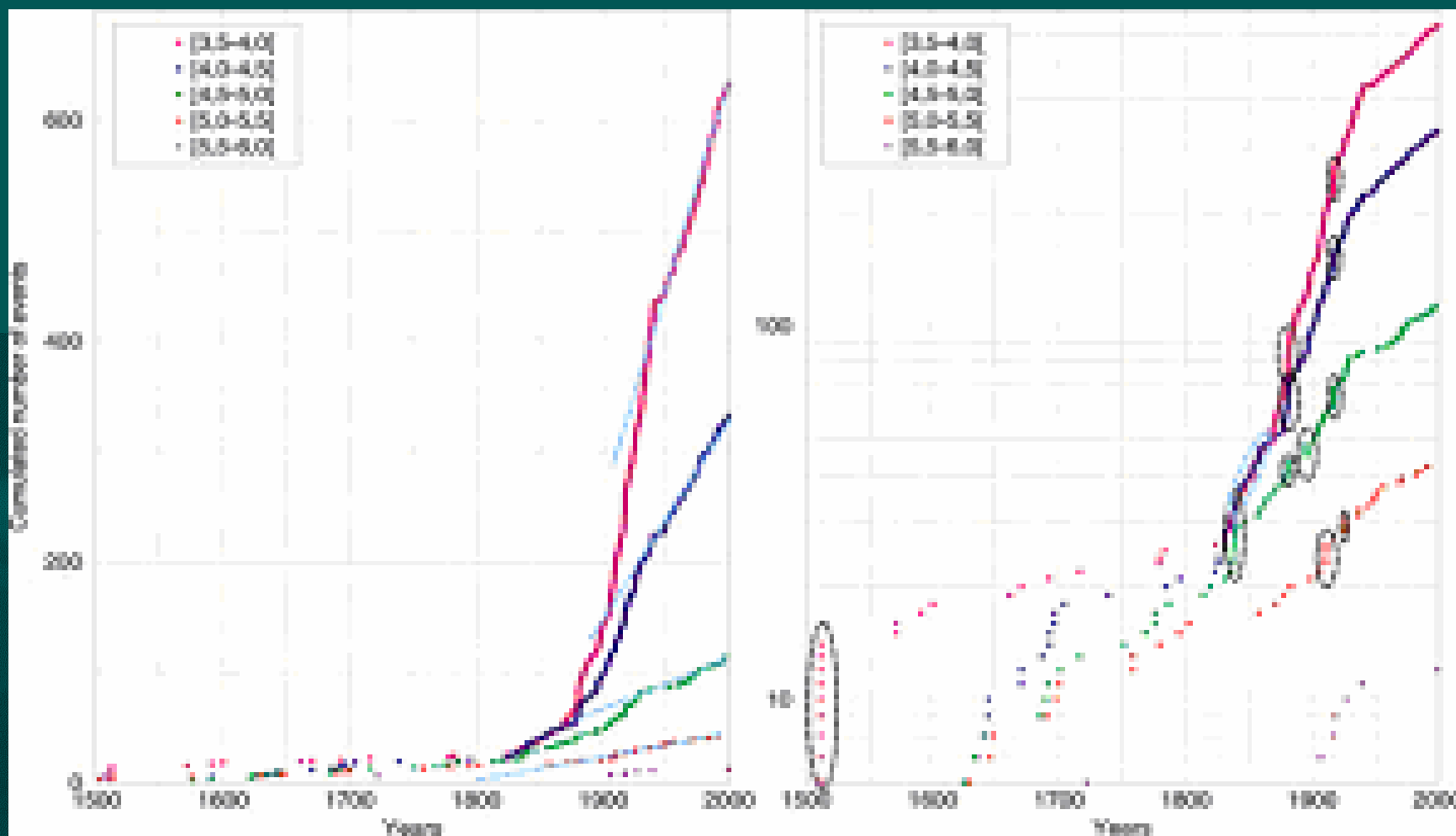
Period:
567 – 2001

$M \geq 4.0$





Analysis of the catalogue

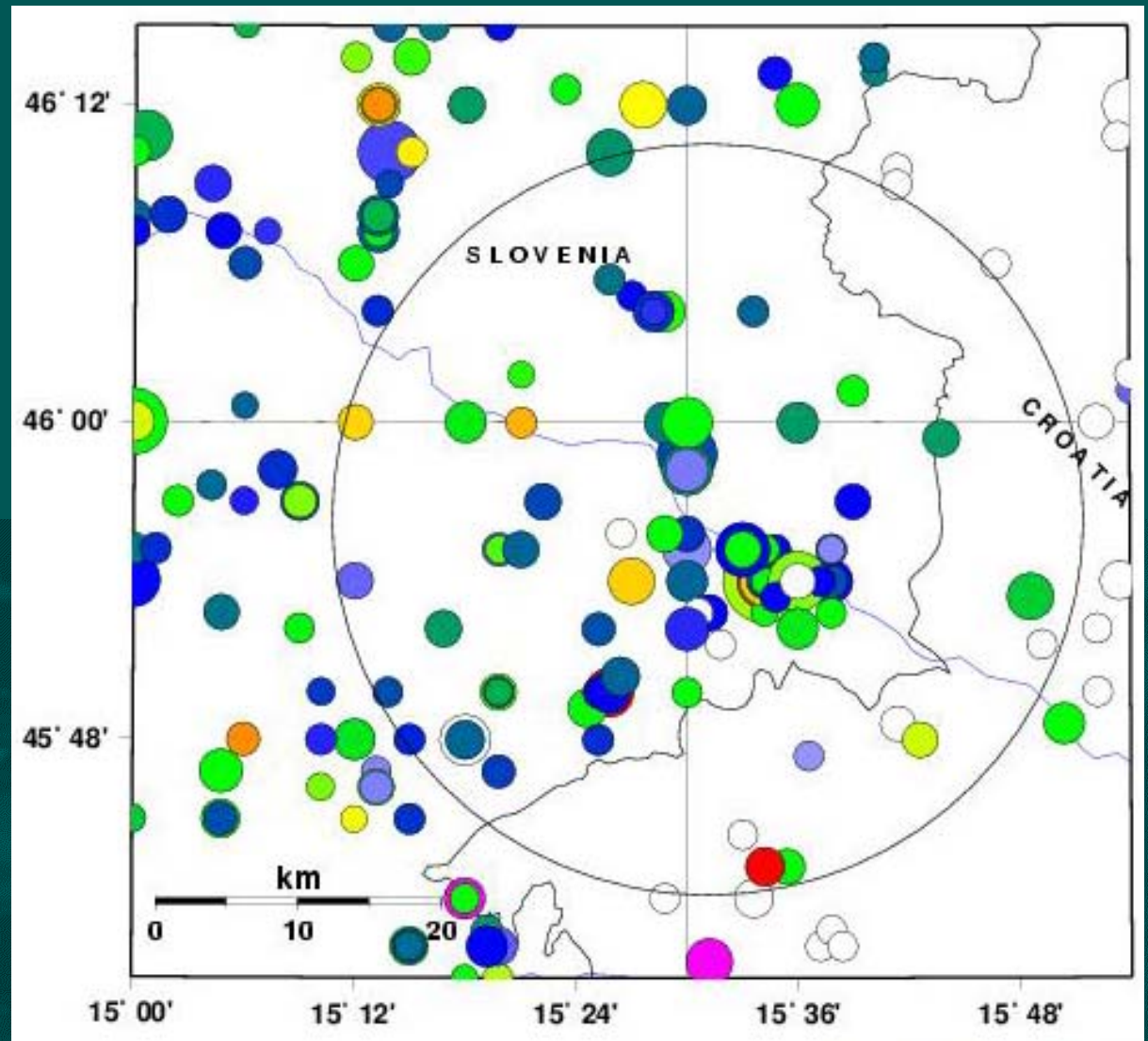
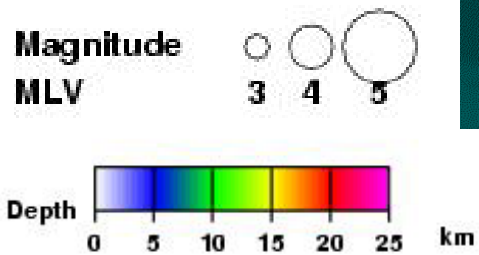




Earthquakes in near regional area

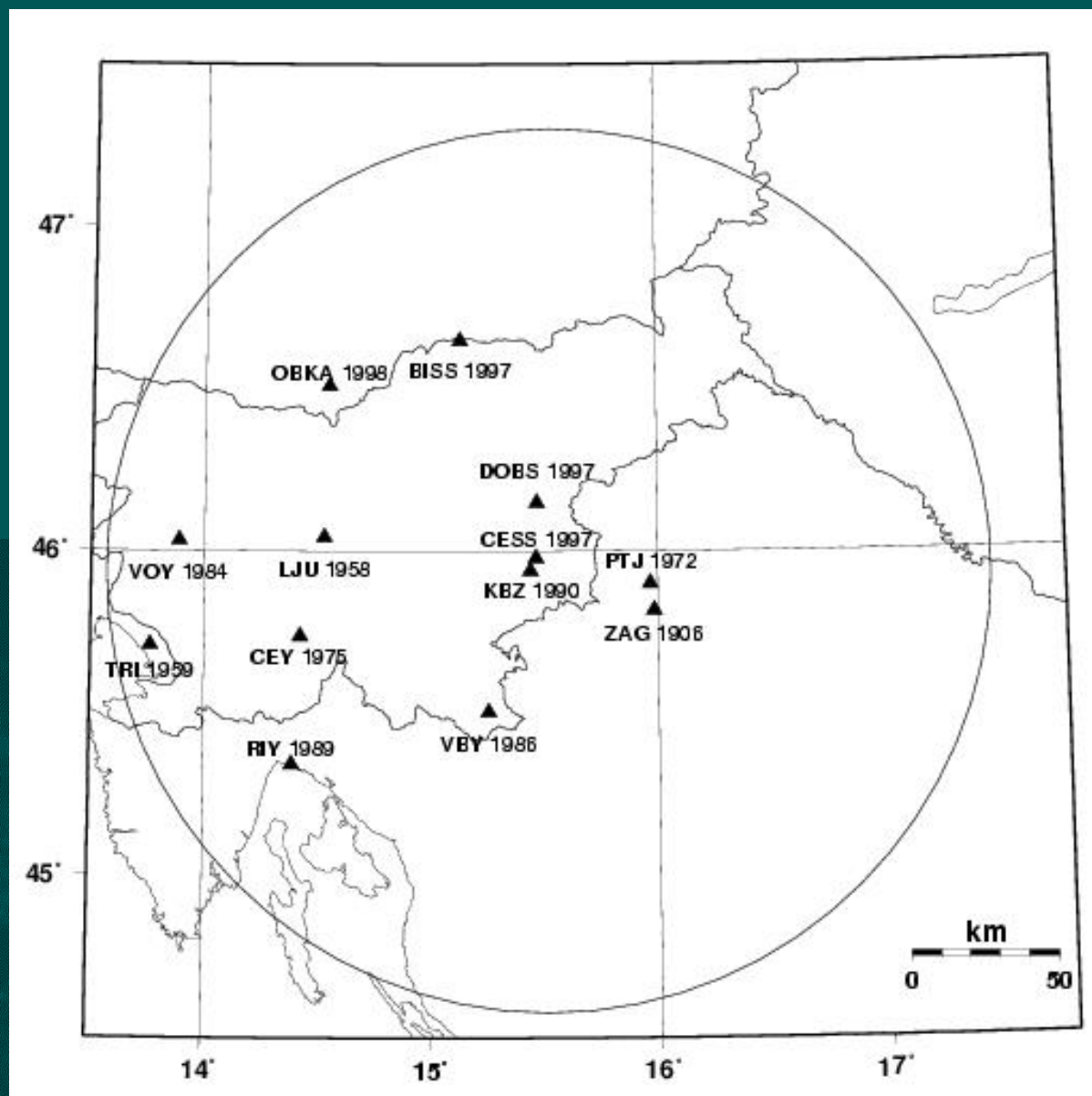
Period:
1628 - 2001

$M \geq 3.5$





Seismic stations within 150 km
from Krško NPP





Revised earthquake catalogue for near regional area

- Period from 1978 to May 2002
- From instrumental data
- Location accuracy ± 5 to 10 km
- Magnitude: M_{LV}

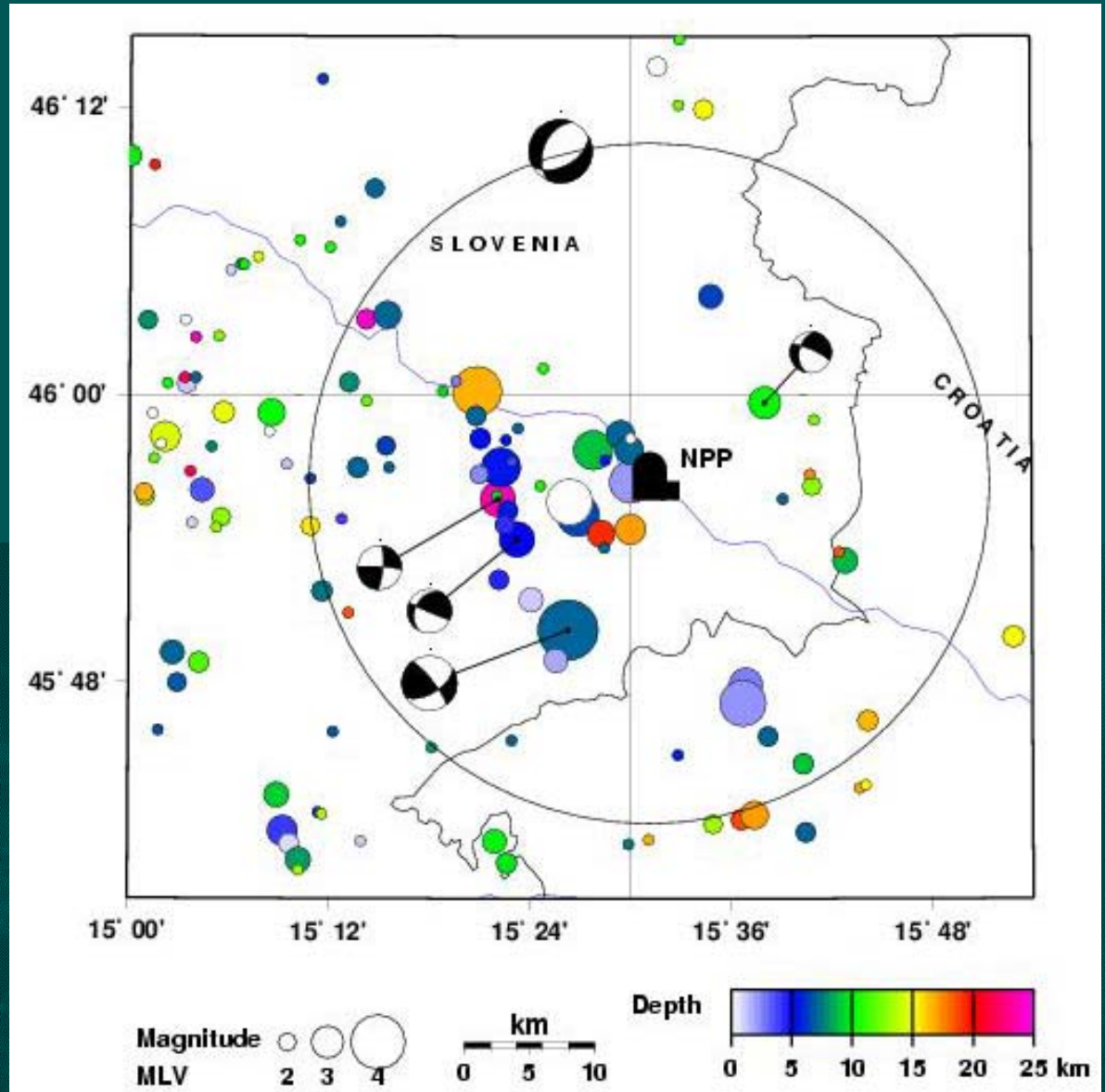


Earthquakes around KNPP
(25 km)
1978 – May 2002

All available instrumental
data was used
Earthquakes relocated
with 1-D model

155 epicentres with smaller
error:

Gap ≥ 180
Nsta ≥ 8





Significant earthquakes

17.06.1628 M=5.0 Krško

04.04.1877 M=5.1 Laško

09.11.1880 M=6.5 Medvednica

17.12.1905 M=5.6 Medvednica

02.01.1906 M=6.1 Medvednica

29.01.1917 M=5.7 Brežice

03.12.1924 M=5.0 Brežice



Conclusions

- Hypocentre accuracy is insufficient for seismotectonic interpretation
- Location and magnitude of significant earthquakes is uncertain