Izvješće uz aktivnost

A4.3 Sudjelovanje na međunarodnoj konferenciji u inozemstvu (M11)

Ana Kuveždić Divjak (poslijedoktorandica), Marin Govorčin (suradnik), Bojan Matoš (suradnik), Almin Đapo (suradnik), Josip Stipčević (konzultant), Boško Pribičević (voditelj)

Istraživački projekt | IP-01-2018-8944 | GEOMSAT

Istraživanje recentnih regionalnih i lokalnih geodinamičkih procesa na području Republike Hrvatske primjenom suvremenih satelitskih geodetskih metoda

Rezultat **D4.3**: Prezentiran rad o prethodnoj primjeni GNSS i MT-InSAR metoda za istraživanje geodinamičkih procesa i prethodnim geološkim i geofizičkim istraživanjima na području RH. Prezentiran rad o metodama kartografske vizualizacije prostornih, tematskih i vremenskih informacija o rezultatima projekta (kartografski znakovi posebno prilagođeni upotrebi na kartama kriza)

- Prilog 1. Potvrda o sudjelovanju na konferenciji
- Prilog 2. Slajdovi s usmenih izlaganja na konferenciji
- Prilog 3. Objavljeni radovi:

Kuveždić Divjak, A., Govorčin, M., Matoš, B., Đapo, A., Stipčević, J., and Pribičević, B.: GEOINFORMATION FOR RESEARCH OF ONGOING GEODYNAMIC PROCESSES IN THE REPUBLIC OF CROATIA, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-3/W8, 233–240, https://doi.org/10.5194/isprs-archives-XLII-3-W8-233-2019, 2019.

Kuveždić Divjak, A., Pribičević, B., and Đapo, A.: COMPARATIVE ANALYSIS OF TAXONOMY, STANDARDISATION AND AVAILABILITY OF CARTOGRAPHIC SYMBOL SETS FOR CRISIS MAPPING, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-3/W8, 241–248, https://doi.org/10.5194/isprs-archives-XLII-3-W8-241-2019, 2019.

Gi4DM 2019 Prague

Auletris event management services

Auletris s.r.o., Tomanova 2302/12a, 16900 Praha 6, Czech Republic

Dr. Ana Kuveždić Divjak
Faculty of Geodesy, University of Zagreb
Geodetski fakultet (Faculty of Geodesy)
Kačićeva 26
10000 Zagreb
Croatia

Auletris s.r.o.
Martin Haloun
Tomanova 2302/12a
CZ-16900 Praha 6
Czech Republic

Prague, Czech Republic, 06/Sep/2019

To Whom It May Concern

Dear Sir or Madam,

We confirm that **Dr. Ana Kuveždić Divjak** participated at Gi4DM 2019 Conference.

Dr. Ana Kuveždić Divjak is author/co-author of the following accepted contribution(s):

Geoinformation for research of ongoing geodynamic processes in the Republic of Croatia
Author(s): Kuveždić Divjak, Ana; Govorčin, Marin; Matoš, Bojan; Đapo, Almin; Pribičević, Boško
Presenting Author: Kuveždić Divjak, Ana

A Comparative Assessment of Cartographic Symbol Sets for Crisis Mapping
Author(s): Kuveždić Divjak, Ana; Pribičević, Boško; Đapo, Almin
Presenting Author: Kuveždić Divjak, Ana

With best regards,

Auletris, s.r.o.
Tomanova 12a, Praha 6, 169 00
IČ: 247 44 182 DIČ: CZ24744182

Martin Haloun
Auletris, s.r.o.
Gi4DM 2019 Conference Organisers
Local organiser of the conference

Auletris, s.r.o.
Tomanova 12a, Praha 6, 169 00
IČ: 247 44 182 DIČ: CZ24744182

Gi4DM 2019
GeoInformation For Disaster Management

Prague
September 5, 2019

HRZZ Croatian Science Foundation
GEOMSAT

Geoinformation for Research of Ongoing Geodynamic processes in the Republic of Croatia

Ana Kuveždić Divjak[1], Marin Govorčin[1], Bojan Matoš[2], Almin Đapo[1], Josip Stipčević[3] and Boško Pribičević[1]

University of Zagreb
FACULTY OF GEODESY

University of Zagreb
FACULTY OF MINING, GEOLOGY AND PETROLEUM ENGINEERING

University of Zagreb
DEPARTMENT OF GEOPHYSICS
FACULTY OF SCIENCE

INTRODUCTION

Geodynamics

- processes occurring in the Earth’s interior, particularly as regards their effects on the crust and its superficial zone

INTRODUCTION

Geodynamics

- processes occurring in the Earth’s interior, particularly as regards their effects on the crust and its superficial zone

Research and monitoring of surface geodynamic processes

- understanding of the mechanisms that lead to seismic activity, i.e. earthquakes

→ interdisciplinary approach of various geosciences

INTRODUCTION

Geodynamics

- processes occurring in the Earth’s interior, particularly as regards their effects on the crust and its superficial zone

Research and monitoring of surface geodynamic processes

- understanding of the mechanisms that lead to seismic activity, i.e. earthquakes

→ interdisciplinary approach of various geosciences

GEODESY

GEOLOGY

SEISMOLOGY

INTRODUCTION

Research and monitoring of surface geodynamic processes

GEODESY

GEOLOGY

SEISMOLOGY

INTRODUCTION

Research and monitoring of surface geodynamic processes

Research activities that investigate accumulation and release of seismic energy, i.e., earthquakes

GEODESY

GEOLOGY

SEISMOLOGY

INTRODUCTION

Research and monitoring of surface geodynamic processes

Research activities that investigate accumulation and release of seismic energy, i.e., earthquakes

Analysis of geological and geophysical data → defining timing of structure evolution, structural-geological relationships, identification of principal discontinuities i.e., faults

Determination of kinematic properties of active faults, as well as their geometrical parameters, which are crucial in definition of fault's seismic potential

Historical and instrumental seismic activity for better defining of seismic hazard, characterization of stress distribution and tectonic processes

GEODESY

GEOLOGY

SEISMOLOGY

INTRODUCTION

Research and monitoring of surface geodynamic processes

Collection of geometric information on the distribution of Earth's stress and strain on the global, regional and local level through observations in exclusive time period with respect to reference frame

GEODESY

Research activities that investigate accumulation and release of seismic energy, i.e., earthquakes

Analysis of geological and geophysical data → defining timing of structure evolution, structural-geological relationships, identification of principal discontinuities i.e., faults

GEOLOGY

Determination of kinematic properties of active faults, as well as their geometrical parameters, which are crucial in definition of fault's seismic potential

Historical and instrumental seismic activity for better defining of seismic hazard, characterization of stress distribution and tectonic processes.

SEISMOLOGY

INTRODUCTION

Research and monitoring of surface geodynamic processes

Collection of geometric information on the distribution of Earth's stress and strain on the global, regional and local level through observations in exclusive time period with respect to reference frame

INTRODUCTION

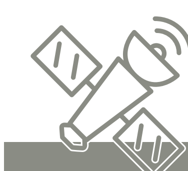
Research and monitoring of surface geodynamic processes

Collection of geometric information on the distribution of Earth's stress and strain on the global, regional and local level through observations in exclusive time period with respect to reference frame

Geodetic methods at the local level
--> basis for monitoring seismic cycles on seismogenic sources

GEODESY

GNSS



InSAR

INTRODUCTION

Research and monitoring of surface geodynamic processes

Collection of geometric information on the distribution of Earth's stress and strain on the global, regional and local level through observations in exclusive time period with respect to reference frame

Geodetic methods at the local level
--> basis for monitoring seismic cycles on seismogenic sources

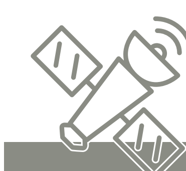
INTER-SEISMIC PHASE
stress accumulation process, i.e. ground deformations that precede earthquake

COSEISMIC PHASE
ground and surface displacements caused by earthquake released energy

POSTSEISMIC PHASE
ground and surface deformations after earthquake event

GEODESY

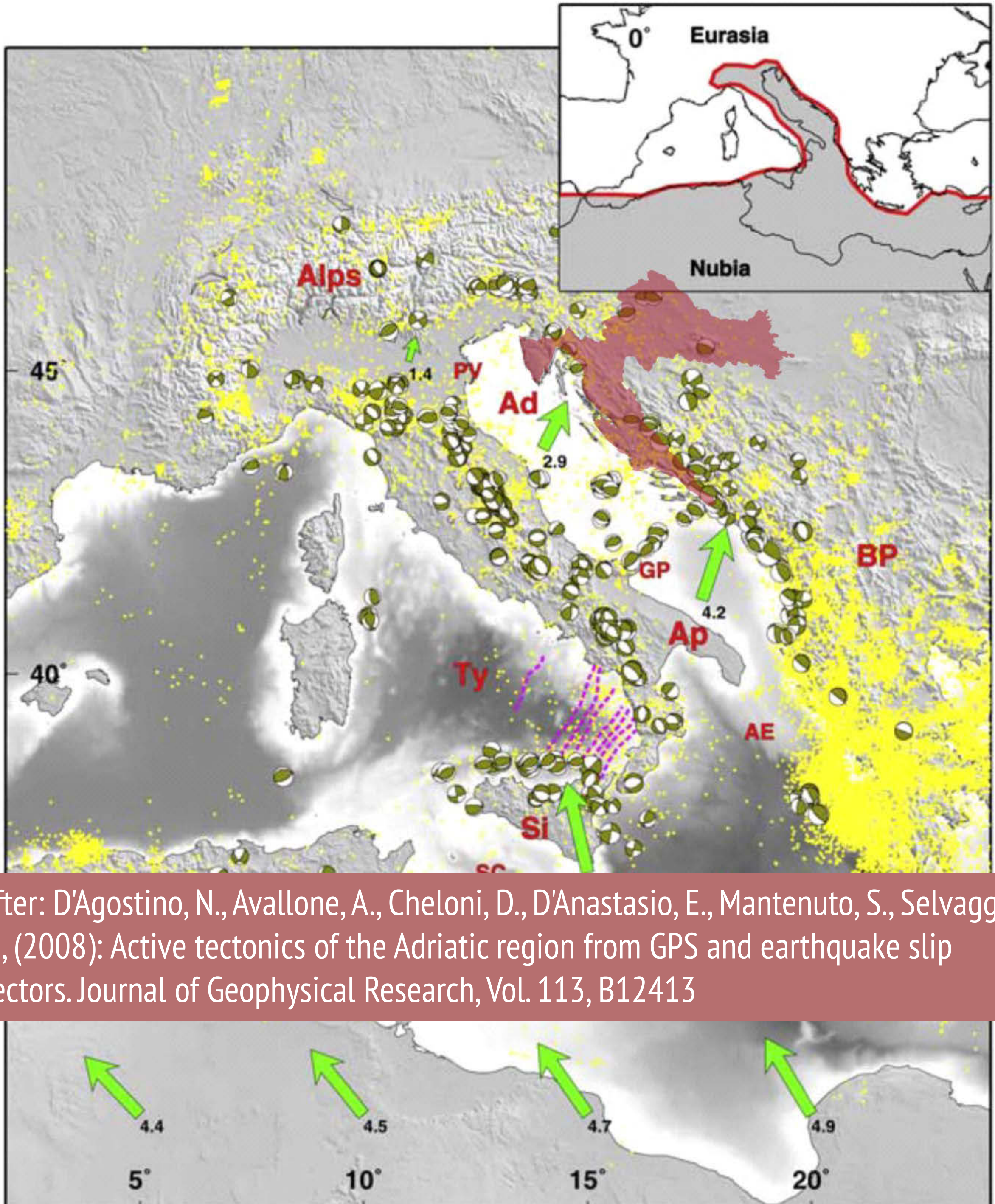
GNSS



InSAR

INTRODUCTION

Republic of Croatia



After: D'Agostino, N., Avallone, A., Cheloni, D., D'Anastasio, E., Mantenuto, S., Selvaggi, G., (2008): Active tectonics of the Adriatic region from GPS and earthquake slip vectors. Journal of Geophysical Research, Vol. 113, B12413

INTRODUCTION

Republic of Croatia

- recent geodynamic processes that manifest through ongoing seismic activity represent a potential risk for the population living in the area
- possible sources of geoinformation that could be used to address the current knowledge on ongoing geodynamic processes in the Republic of Croatia?

INTRODUCTION

Republic of Croatia

- recent geodynamic processes that manifest through ongoing seismic activity represent a potential risk for the population living in the area
- possible sources of geoinformation that could be used to address the current knowledge on ongoing geodynamic processes in the Republic of Croatia?

Geoinformation

- collection and storage of georeferenced data that can be queried by both, attribute and location

Geodesy – GNSS Data for Crustal Deformation Studies

- representative results of geodynamic studies employing GNSS observations carried out in Croatia in the last 30 years:

Geodesy – GNSS Data for Crustal Deformation Studies

- representative results of geodynamic studies employing GNSS observations carried out in Croatia in the last 30 years:

GNSS campaign-mode observations

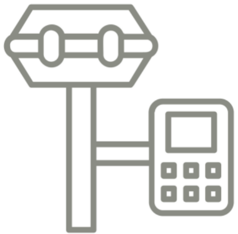
- international geodynamic projects in a form of GNSS campaigns
- 21 GPS campaigns with the purpose of determining geodynamic movements on the Croatian territory
- Geodynamic GPS Network of the City of Zagreb (1997 – today)

➡ RELATIVE VELOCITY FIELDS
available only in a form of scientific publication

Geodesy – GNSS Data for Crustal Deformation Studies

- representative results of geodynamic studies employing GNSS observations carried out in Croatia in the last 30 years:

continuous GNSS



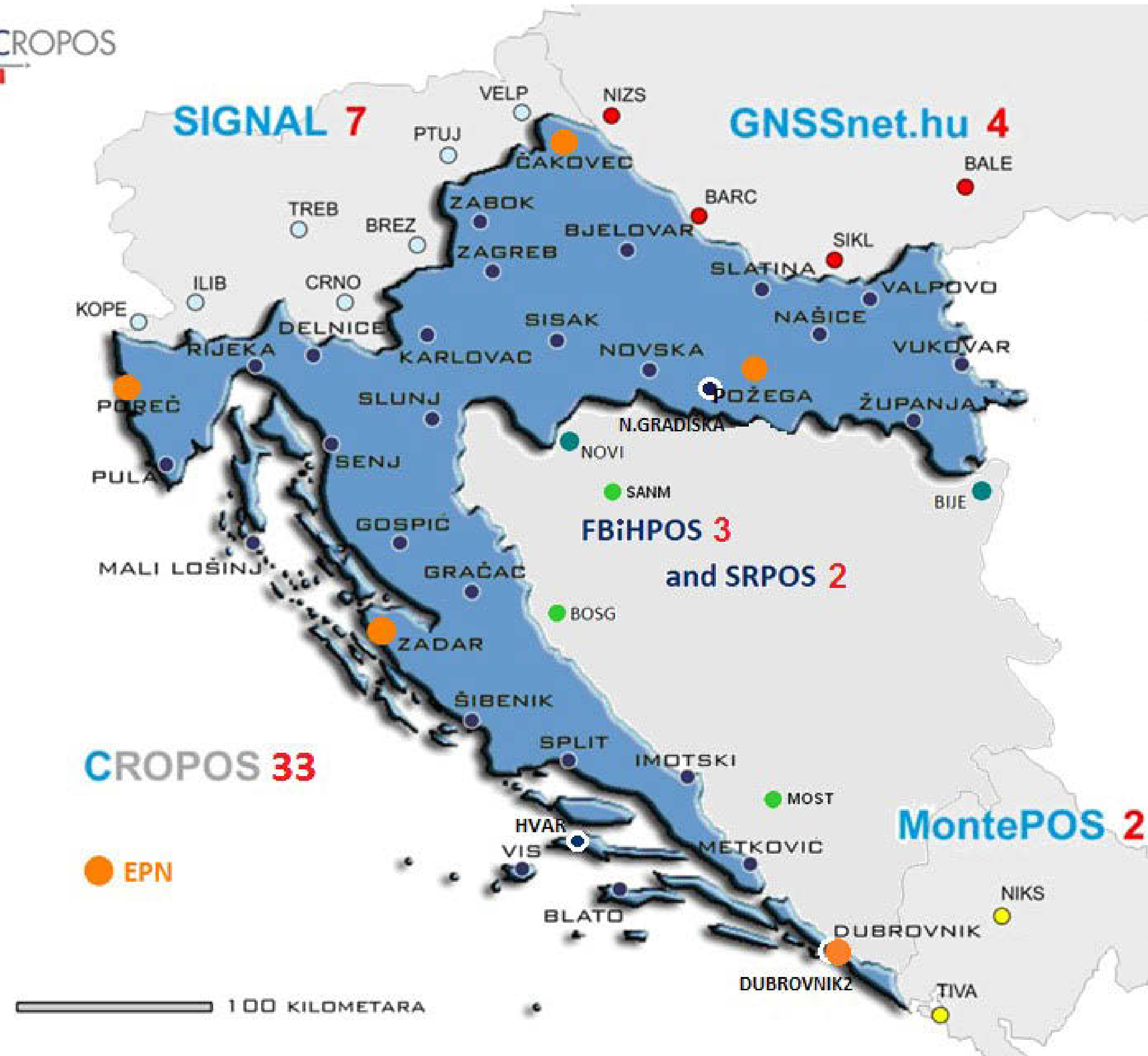
Geodesy – GNSS Data for Crustal Deformation Studies

continuous GNSS

CROPOS

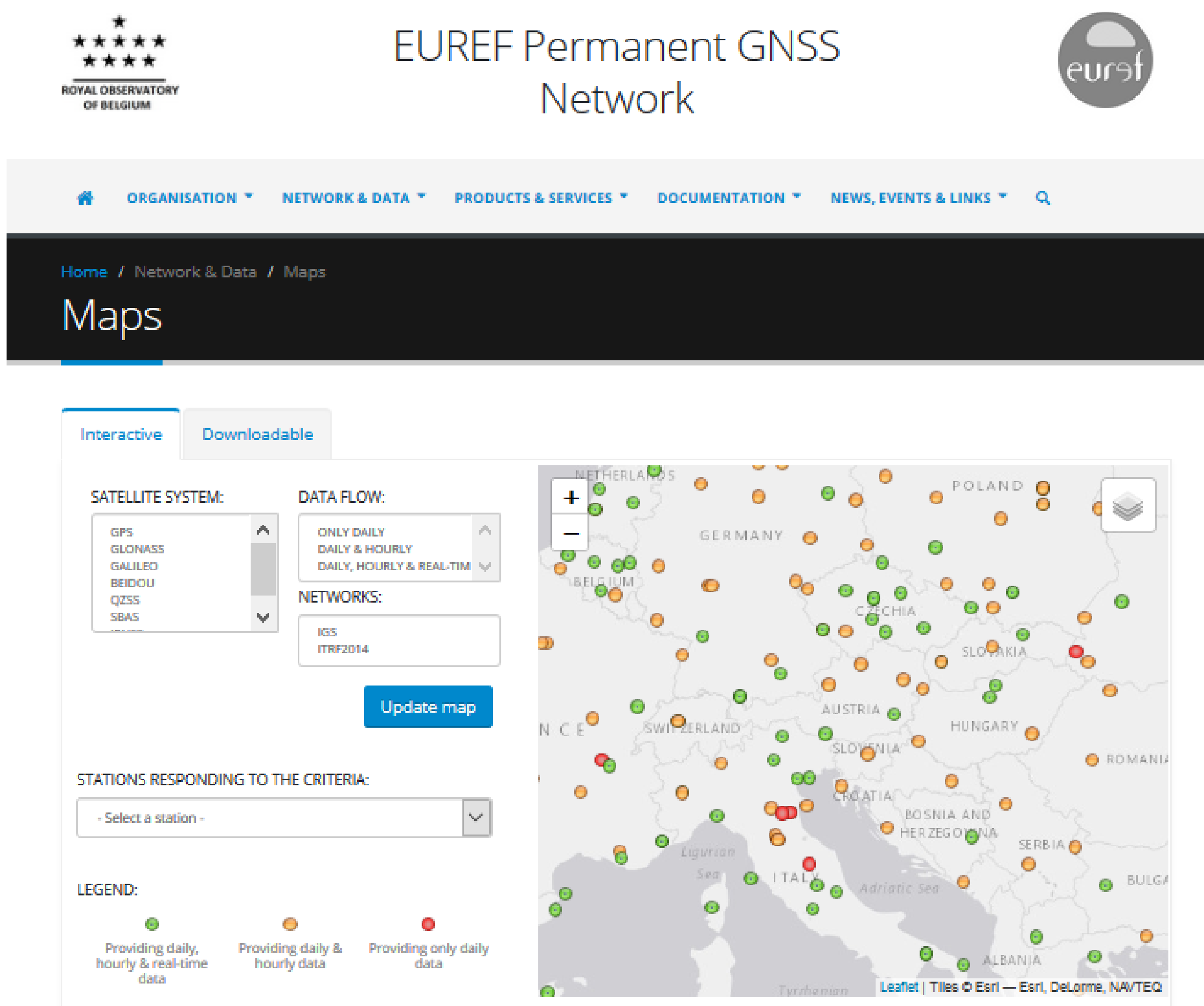
(CROatian POsitioning System) network for determination of Adria microplate geokinematic model

CROPOS



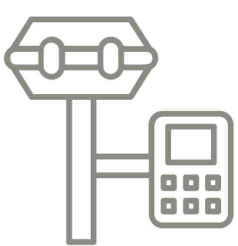
Geodesy – GNSS Data for Crustal Deformation Studies

continuous GNSS



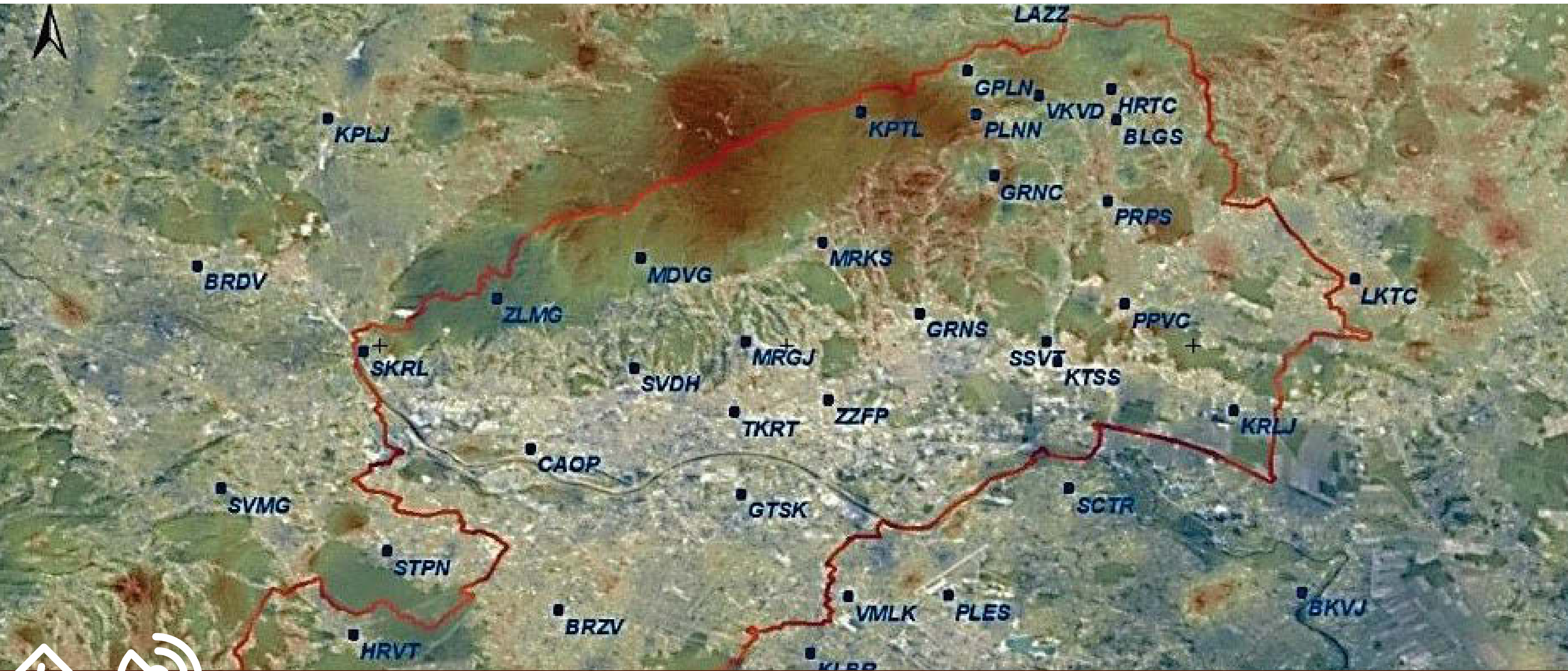
EUREF Permanent Network (EPN)

station positions and velocities (five EPN permanent stations located on the Croatian territory)



Geodesy – InSAR for Global and Dense Remote Sensing of Deformation

- Interseismic ground deformations over the wider Zagreb area

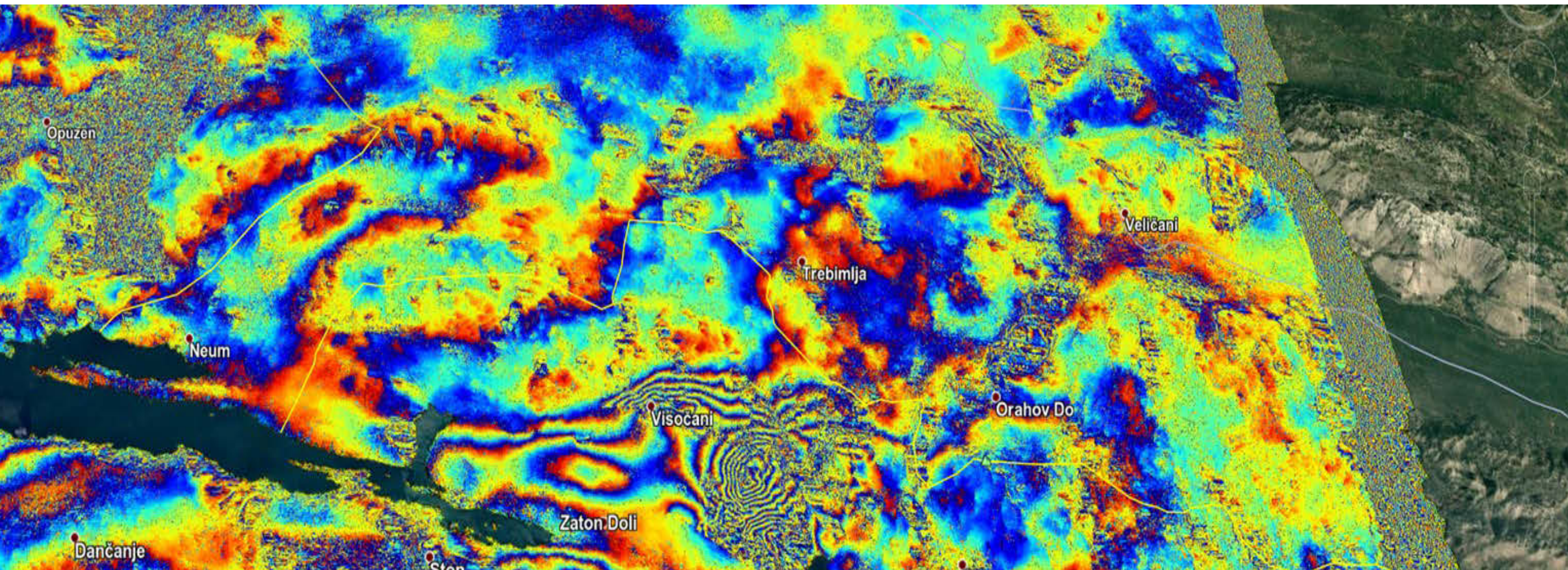


Pribičević, P., Đapo, A., Govorčin, M. (2017): The application of satellite technology in the study of geodynamic movements in the wider Zagreb. Tehnički vjesnik, Vol 24, No.2 pp 503-512

GEOINFORMATION FOR RESEARCH AND MONITORING OF GEODYNAMIC PROCESSES

Geodesy – InSAR for Global and Dense Remote Sensing of Deformation

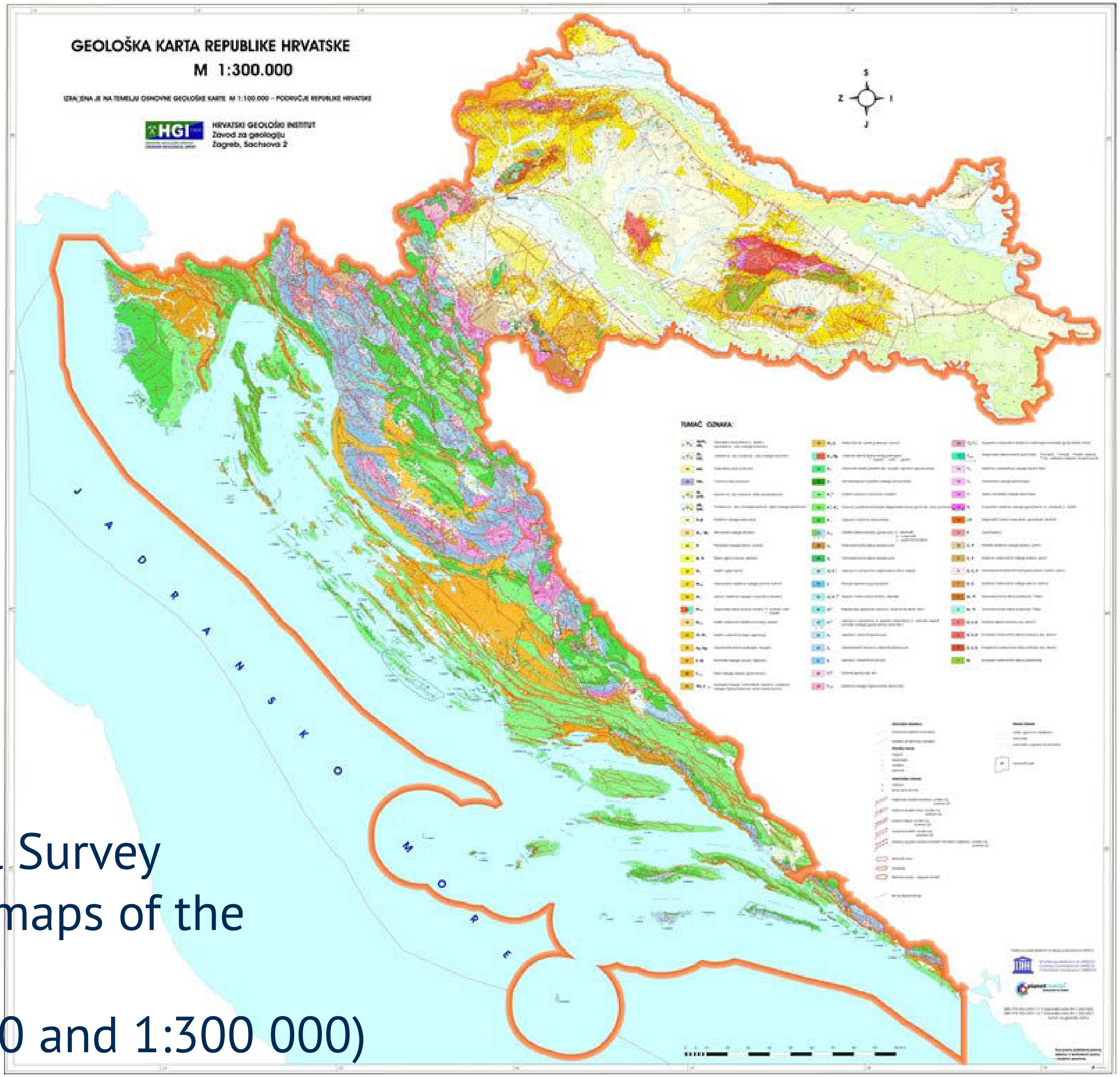
- Coseismic ground deformation of Ston-Slano 1996 ML 6.0 earthquake



Govorčin, M., Matoš, B. Herak, M. Pribičević, B., Vlahović, I. (2018): Coseismic deformation analysis of the 1996 Ston-Slano (southern Croatia) ML 6.0 earthquake: preliminary results using DinSAR and geological investigations. 9th International INQUA Meeting on Paleoseismology, Active Tectonics and Archeoseismology, 25-27 June 2018, Possidi, Greece.

Geology

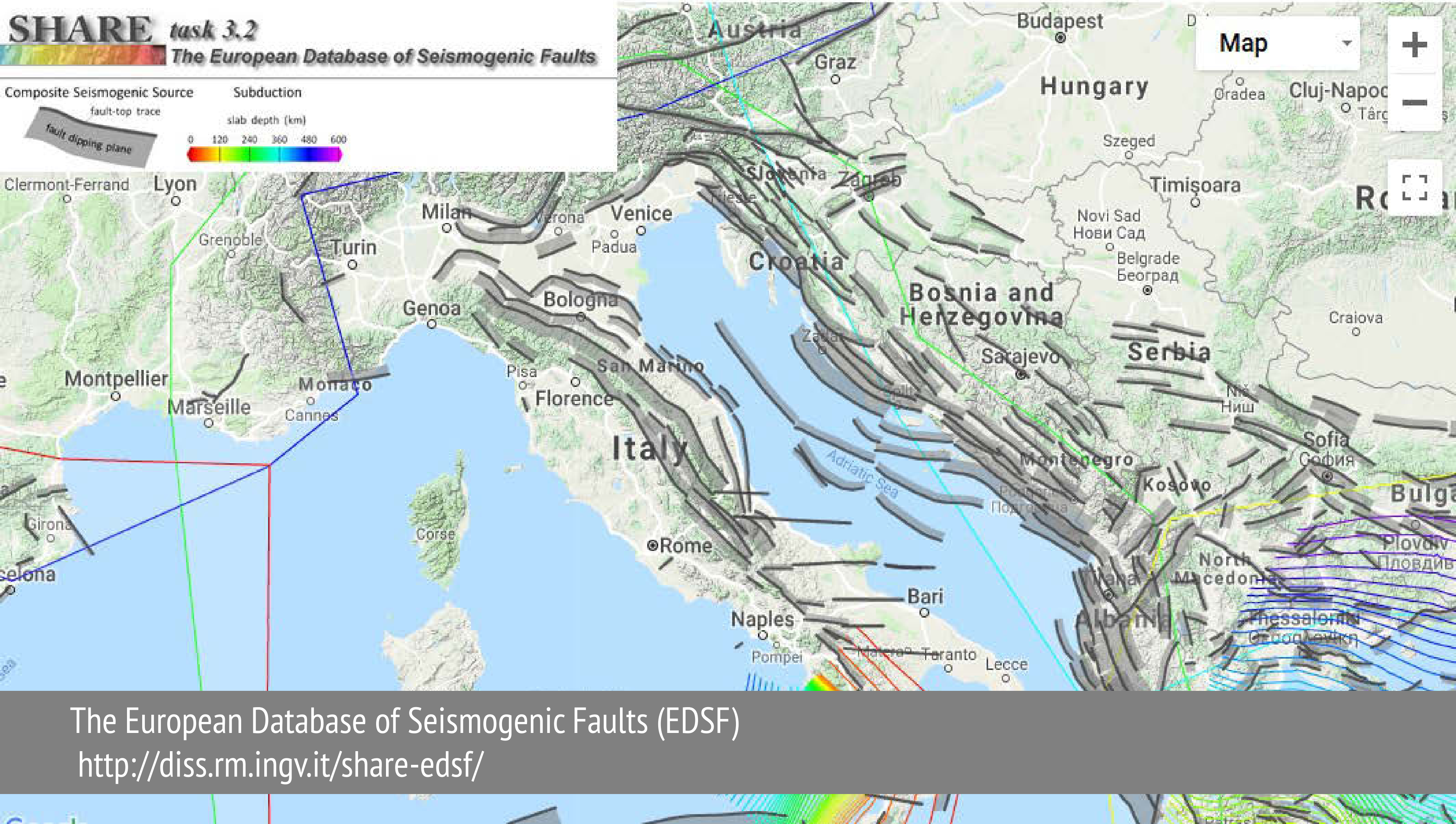
- Structural data from field observations
- Thematic geological maps



- Croatian Geological Survey Official geological maps of the Republic of Croatia (1:50 000, 1:100 000 and 1:300 000)

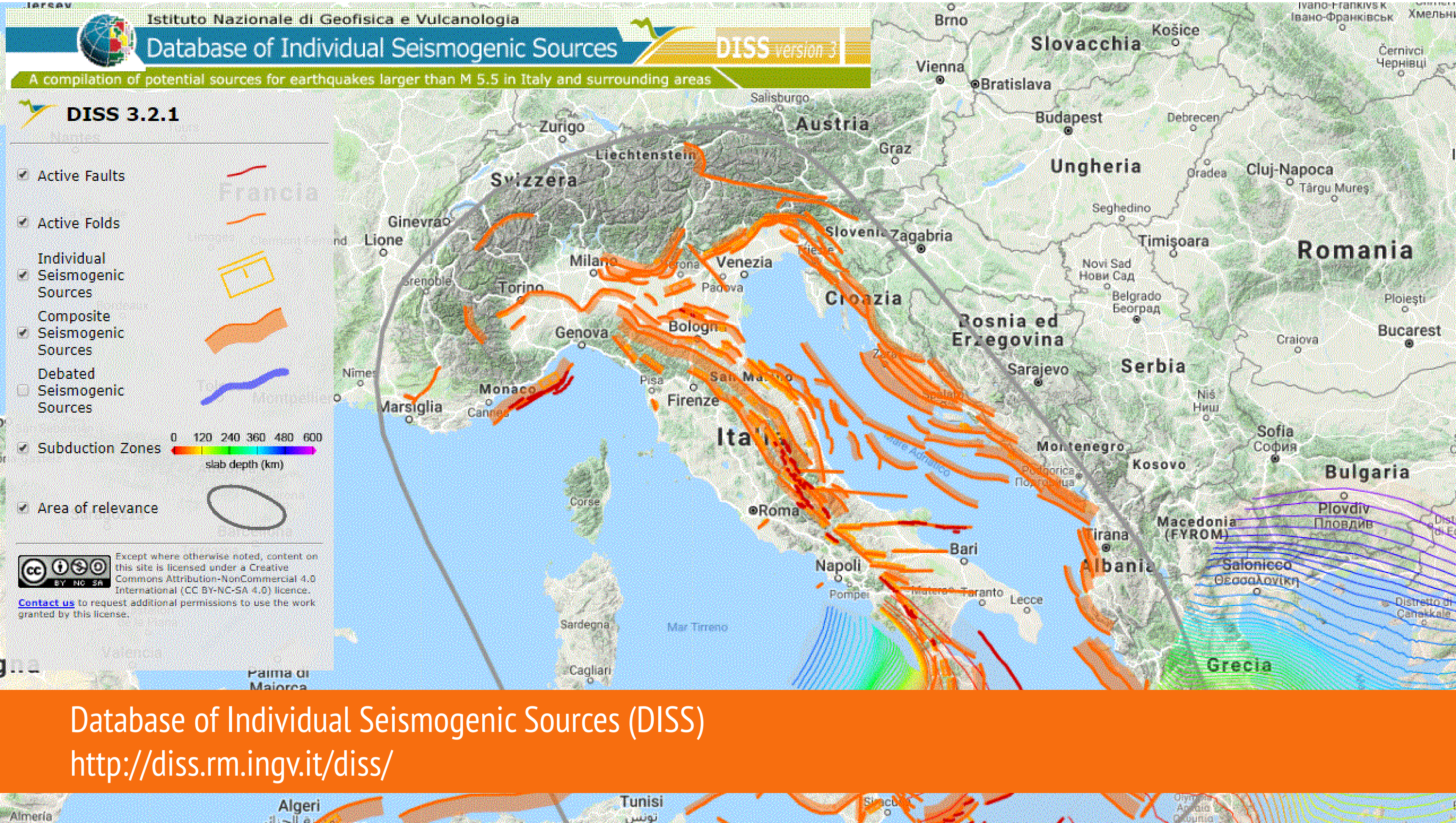
GEOINFORMATION FOR RESEARCH AND MONITORING OF GEODYNAMIC PROCESSES

Geology



The European Database of Seismogenic Faults (EDSF)
http://diss.rm.ingv.it/share-edsf/

Geology

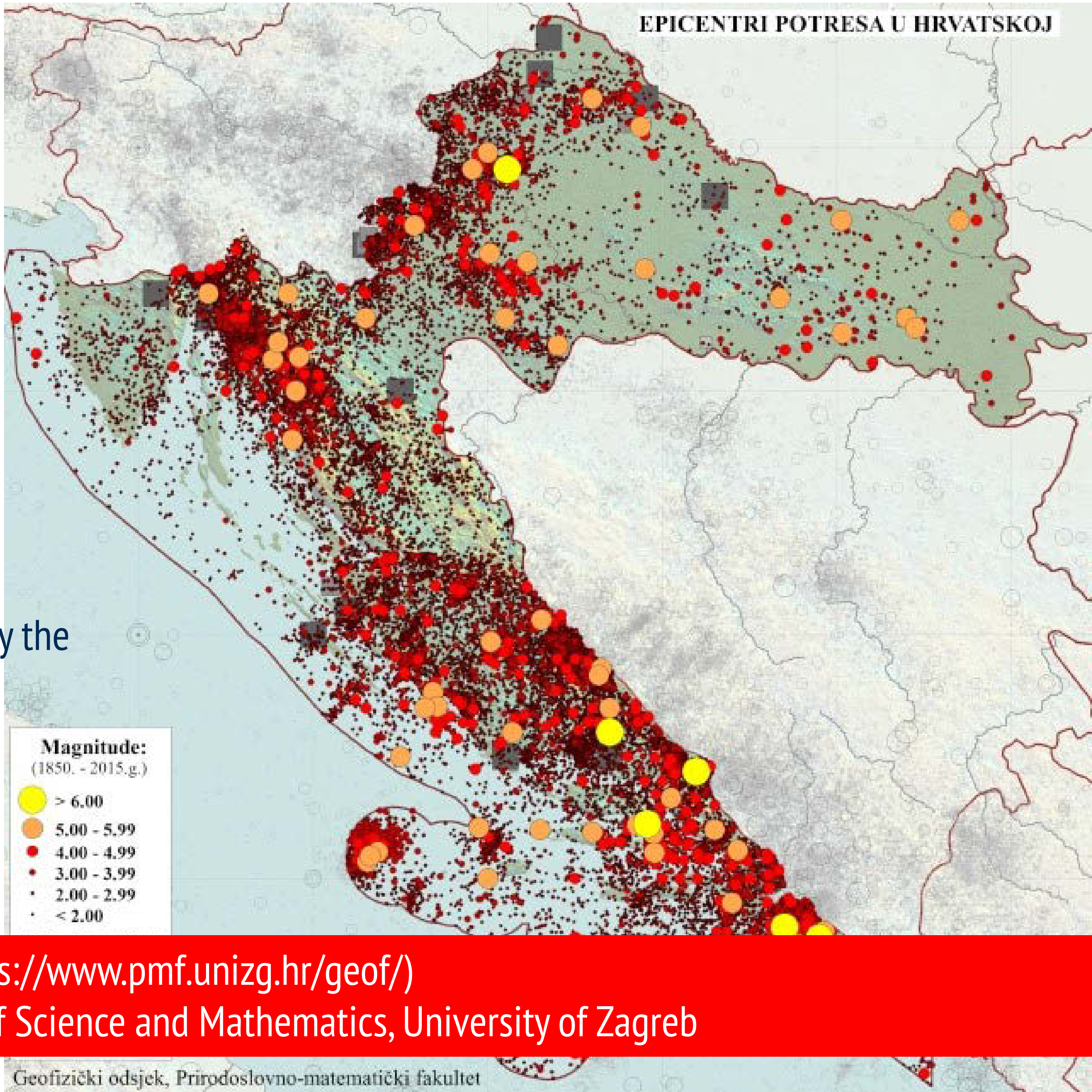


Database of Individual Seismogenic Sources (DISS)
http://diss.rm.ingv.it/diss/

Seismology

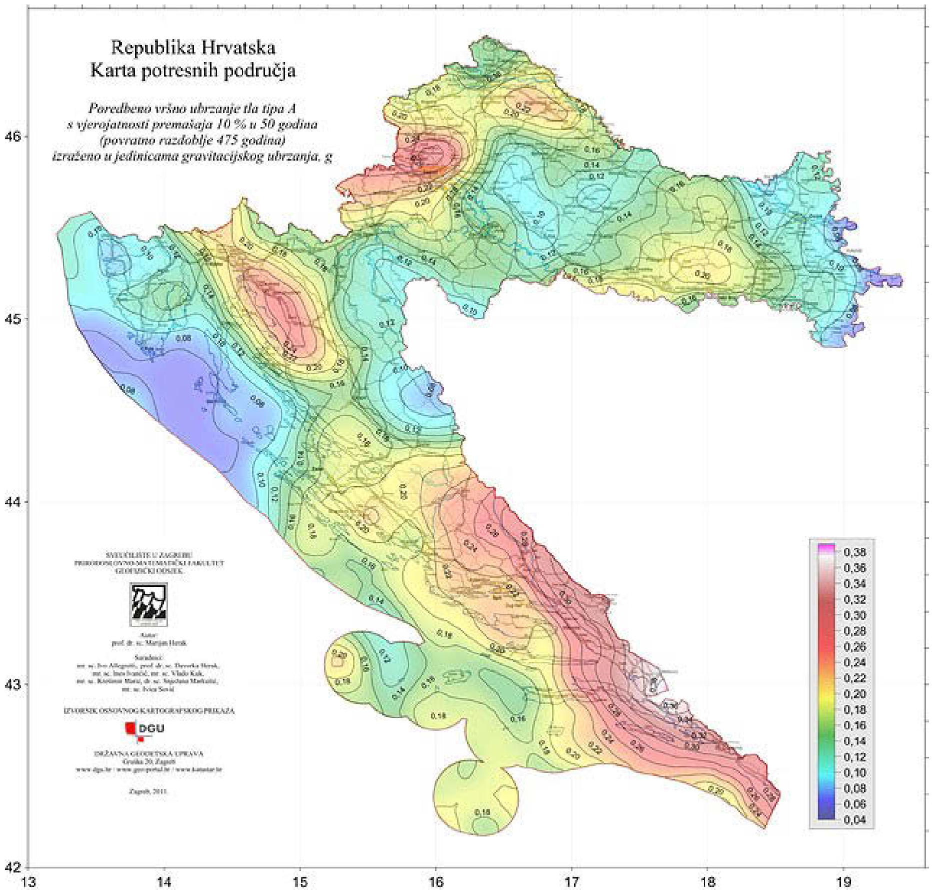
- Earthquake data (seismic wave travel times, earthquake locations, macroseismic reports, earthquake mechanisms)

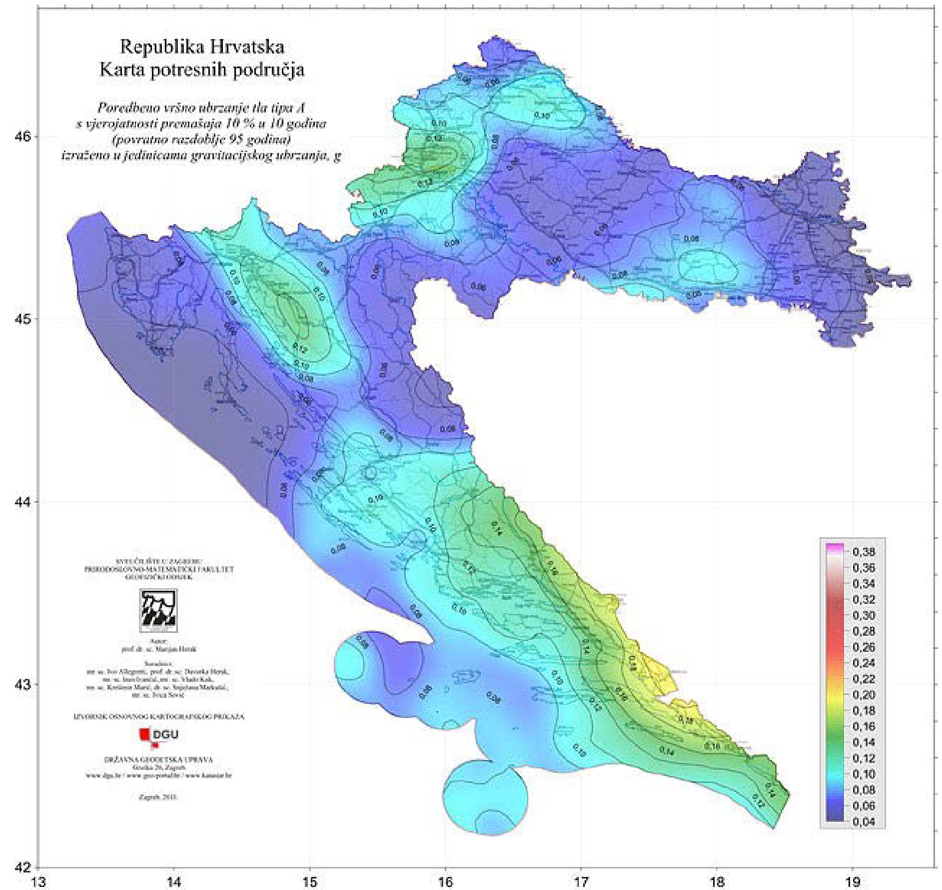
routinely collected and archived by the Department of Geophysics, Faculty of Science, University of Zagreb



Croatian Earthquake Catalogue (https://www.pmf.unizg.hr/geof/)
Department of Geophysics, Faculty of Science and Mathematics, University of Zagreb

Seismology

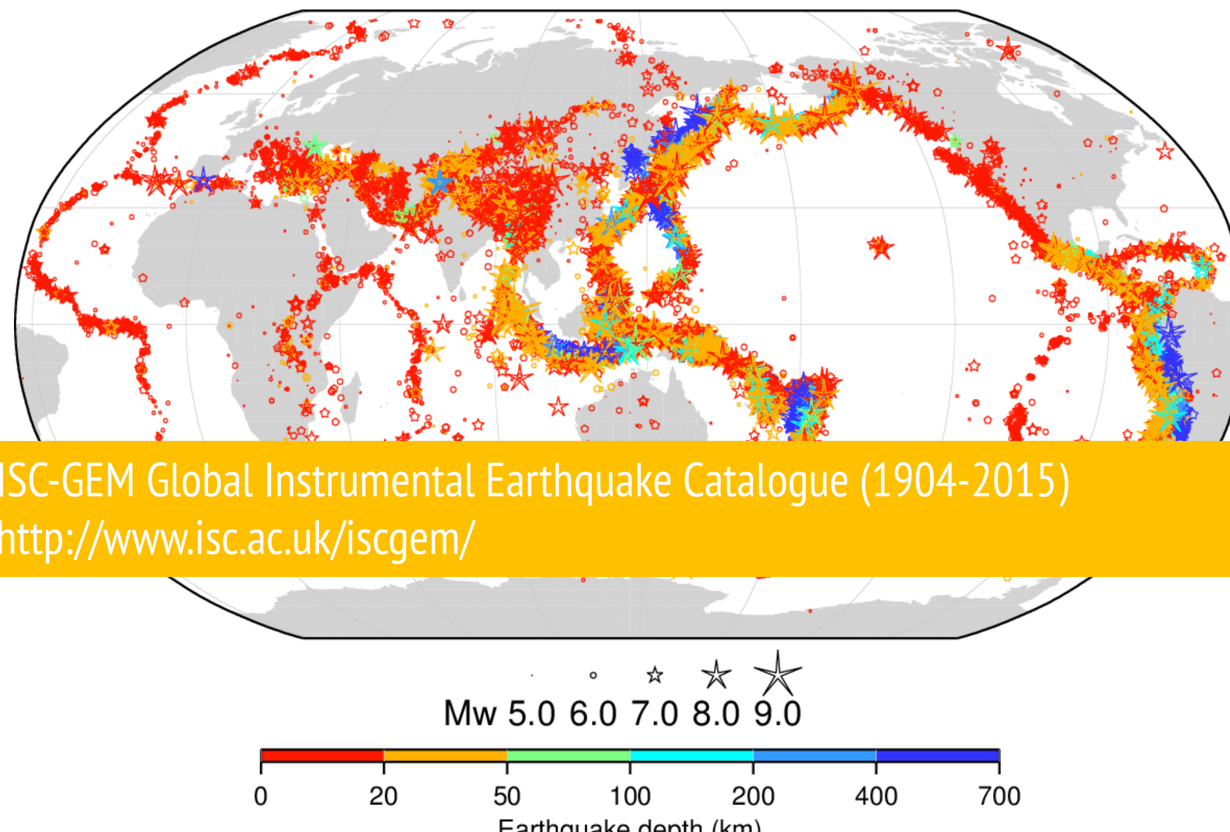




Croatian Earthquake Hazard Maps (http://seizkarta.gfz.hr)
Department of Geophysics, Faculty of Science and Mathematics, University of Zagreb

Seismology

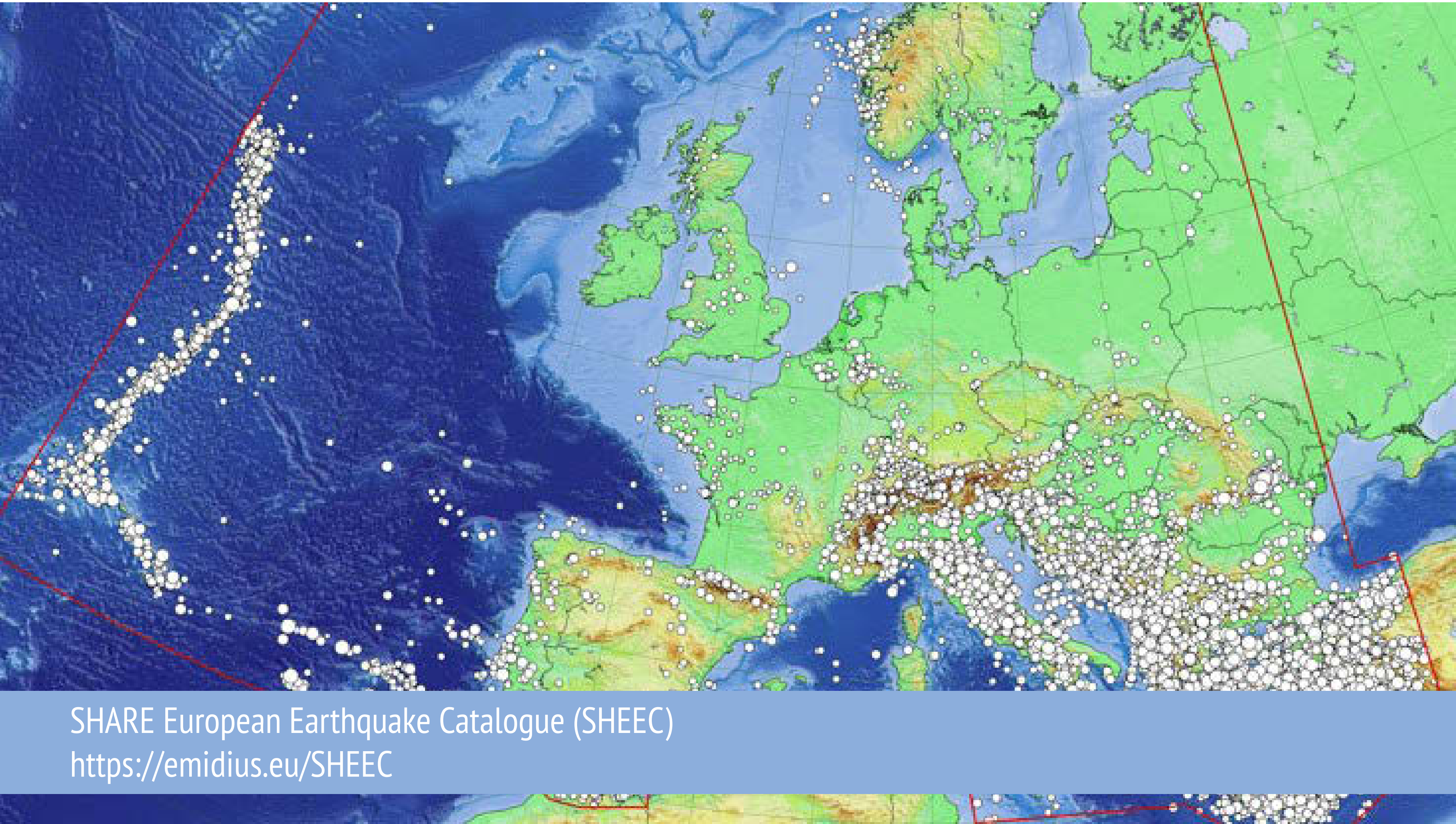
- Seismological data on earthquakes in the wider spatial frame (earthquake focal mechanisms, estimated maximal earthquake magnitude with regard to geometric parameters, focal depth, etc.)



ISC-GEM Global Instrumental Earthquake Catalogue (1904-2015)
http://www.isc.ac.uk/iscgem/

GEOINFORMATION FOR RESEARCH AND MONITORING OF GEODYNAMIC PROCESSES

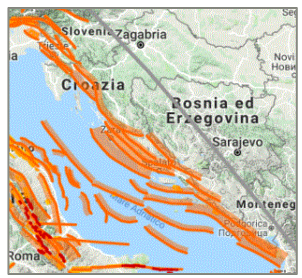
Seismology

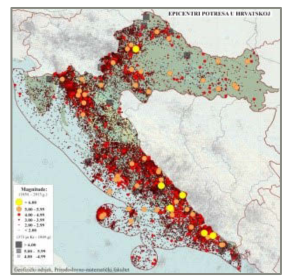


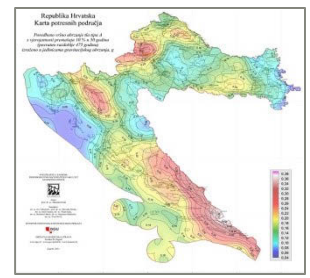
SHARE European Earthquake Catalogue (SHEEC)
https://emidius.eu/SHEEC

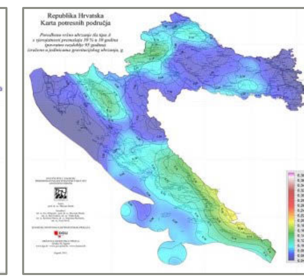
CONCLUSION AND FUTURE WORK

- systematization of spatial data for **geodetic-geodynamic basis** for future research of crustal deformations on the territory of the Republic of Croatia → first step
- publically available sources of the diverse sets of site-specific **geodetic, geological and seismological geospatial data**







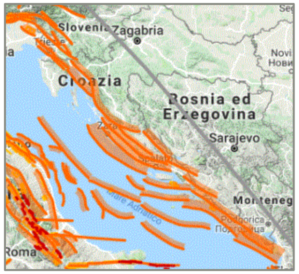
→ identified

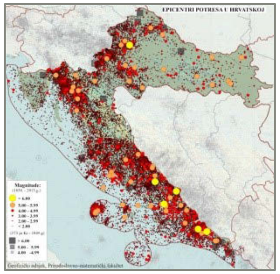
Source title	EUREF Permanent Network (EPN), station positions and velocities	Geological Maps of the Republic of Croatia	The European Database of Seismogenic Faults (EDSF)	Croatian Earthquake Catalogue (CEC)	SHARE European Earthquake Catalogue (SHEEC) 1000-1899	Croatian Earthquake Hazard Maps	COMET-LiCS Sentinel-1 InSAR Portal
Description	A science-driven network of permanent GNSS tracking stations whose weekly computed positions are used by EUREF to realize the European Terrestrial Reference System (ETRS89).	Official geological maps of the Republic of Croatia at the scale of 1:50 000, 1:100 000 and 1:300 000	EDSF includes only faults that are identified and mapped as neotectonics active faults, i.e., possible seismogenic sources capable of generating earthquakes of magnitude equal to or larger than 5.5. It aims to ensure a homogeneous input for use in ground-shaking hazard assessment in the Euro-Mediterranean area.	CEC is the main database about the past and present earthquakes in Croatia covering period from 373 BC until today compiled using all data on earthquakes from the archives of the Department of Geophysics, Faculty of Science, University of Zagreb (the catalogues, macroseismic reports, seismograms, and other related documents).	SHEEC is a European parametric earthquake catalogue, as much homogeneous as possible, which covers the time window 1000–1899. Developed within the frame of the European Commission project SHARE compiled from European Archive of Historical EArthquake Data.	Maps of seismic hazard in Croatia expressed by the probability of exceedance of PGA for return periods of 475 years and 95 years.	Online Catalog of Sentinel-1 generated interferograms and coherence maps. Results are available for download as Derived Works of Copernicus data (2015–2016) through interactive online map. Products are: Unfiltered wrapped phase (Quicklook, Magnitude, Phase), Coherence (Quicklook, Phase) and filtered unwrapped phase (quicklook, unwrapped interferogram)
Responsible organization	IAG (International Association of Geodesy) Regional Reference Frame sub-commission for Europe, EUREF.	Croatian Geololgical Survey	Italian National Institute of Geophysics and Volcanology (INGV)	Department of Geophysics, Faculty of Science and Mathematics, University of Zagreb	Istituto Nazionale di Geofisica e Vulcanologia, Milan	Department of Geophysics, Faculty of Science and Mathematics, University of Zagreb	COMET, School of Earth and Environment, University of Leeds, England
Source locator	http://www.epncb. oma.be	http://www.hgi-cgs. hr/geoportal.htm	http://diss.rm.ingv.it/ share-edsf	https://www.pmf.unizg.hr/geof/	https://emidius.eu/SHEEC	http://seizkarta.gfz.hr	https://comet.nerc.ac.uk/COMET-LiCS-portal
Source type	spatial dataset	spatial dataset	spatial dataset	spatial dataset	spatial dataset	spatial dataset	service
Distribution format	SINEX	PDF, 1:300 000 also as web application	MapInfo mif/mid ESRI shapefile	textual	MS Excel, Interactive web application	PDF, Interactive application	Raster (geotiff)
Reference coordinate system	Geocentric coordinate system for Europe	Projected coordinate system for Croatia HTRS96 / TM	Geodetic coordinate system for World	Geodetic coordinate system for World	Geodetic coordinate system for World	No standard map projection, orthogonal coordinates	Geodetic coordinate system for World
Temporal coverage	Start date: 1995	1982– (1:50 000), 1962–1992 (1:100 000), 2006–2009 (1:300 000)	n/a	Covers the period since 373 BC until today	Time window 1000–1899	Published in 2011	02.09.2016–31.05.2018
Spatial resolution	Station distances between 100 and 500 km or more.	Map scale: 1:50 000, 1:100 000, 1:300 000	n/a	n/a	n/a	Map is compiled at the approximate scale of 1:800 000	260 km x 360 km (per product)
Temporal resolution	Daily Hourly	Does not require frequent updating.	n/a	Regularly updated.	n/a	Planned revision and update every 5–7 years.	12 days
Restrictions and terms of use	Freely available.	Purchase or inquiry upon request.	Designed as "work in progress", and as such it is open to later additions and improvements	Croatian Earthquake Catalogue (CEC) is not available on line. It is stored in the archives of the Department of Geophysics of the Faculty of Science, University of Zagreb.	Open-access upon registration. It can be used for scientific purposes, only, quoting the reference indicated.	Freely available for download as PDF in full resolution. The maps were accepted as a part of the Croatian National Annex to the EC8 in 2012.	Open-access

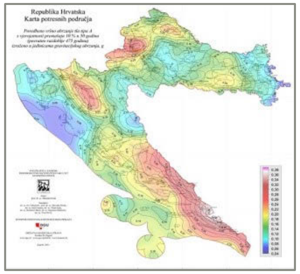
Overview of the availability, scale, precision and usage of the possible sources of geoinformation that could be used to address the current knowledge on ongoing geodynamic processes in Croatia

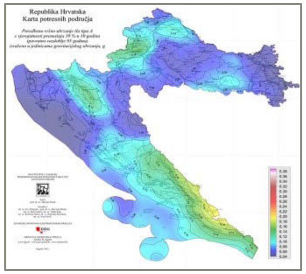
CONCLUSION AND FUTURE WORK

- systematization of spatial data for **geodetic-geodynamic basis** for future research of crustal deformations on the territory of the Republic of Croatia → first step
- publically available sources of the diverse sets of site-specific **geodetic, geological and seismological geospatial data**





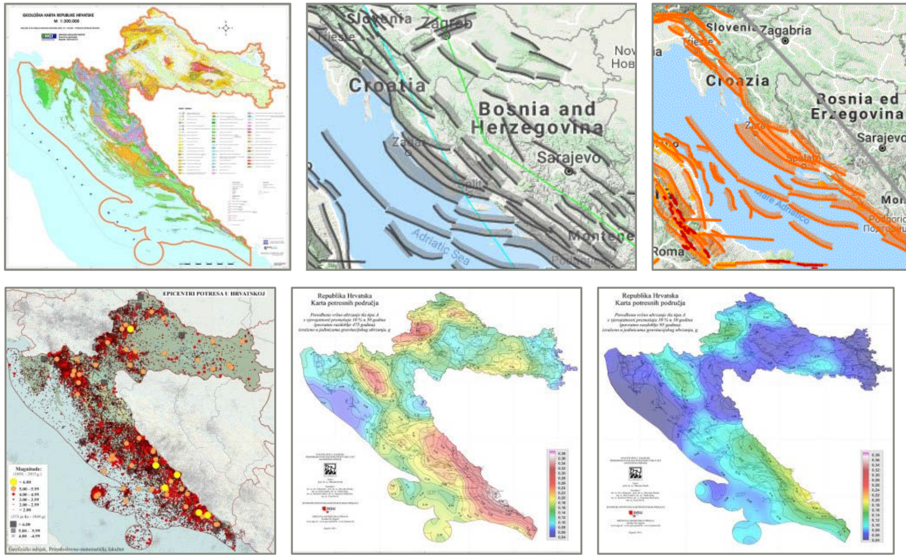


→ problems exist related to availability, organization, and sharing

→ online database with visualization and sharing services of the existing and future geodetic data for geodynamic research in the Republic of Croatia

THANK YOU FOR YOUR ATTENTION!

Ana Kuveždić Divjak
akuvezdic@geof.hr
Faculty of Geodesy, University of Zagreb



This work has been fully supported by the Croatian Science Foundation under the project number IP-01-2018-8944.

Gi4DM 2019

GeoInformation For Disaster Management

Prague September 5, 2019

Comparative Analysis of Taxonomy, Standardisation and Availability of Cartographic Symbol Sets for Crisis Mapping

Ana Kuveždić Divjak, Boško Pribičević, Almin Đapo

University of Zagreb, Faculty of Geodesy

Gi4DM 2019

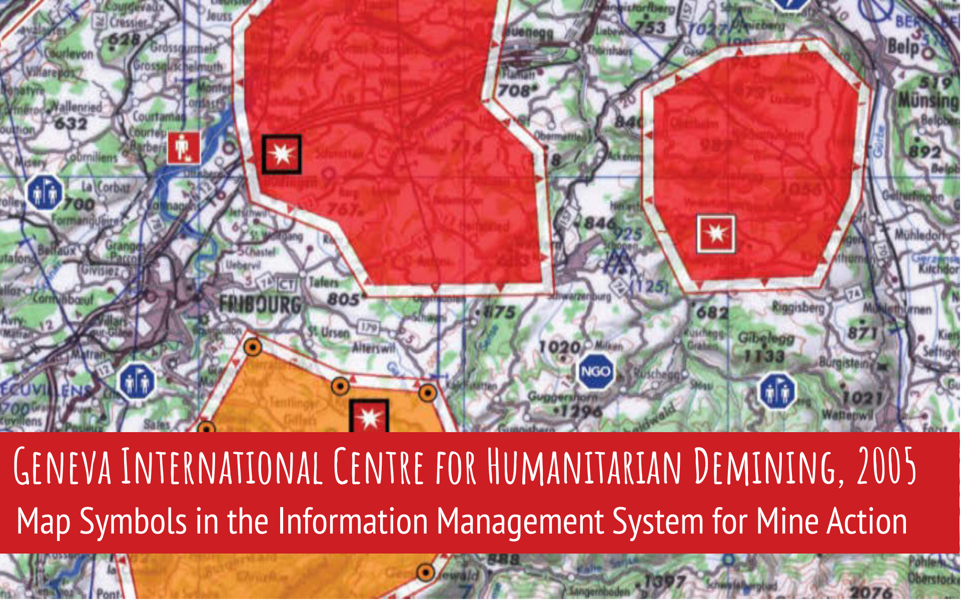
GeoInformation For Disaster Management

Prague September 5, 2019

Comparative Analysis of Taxonomy, Standardisation and Availability of Cartographic Symbol Sets for Crisis Mapping

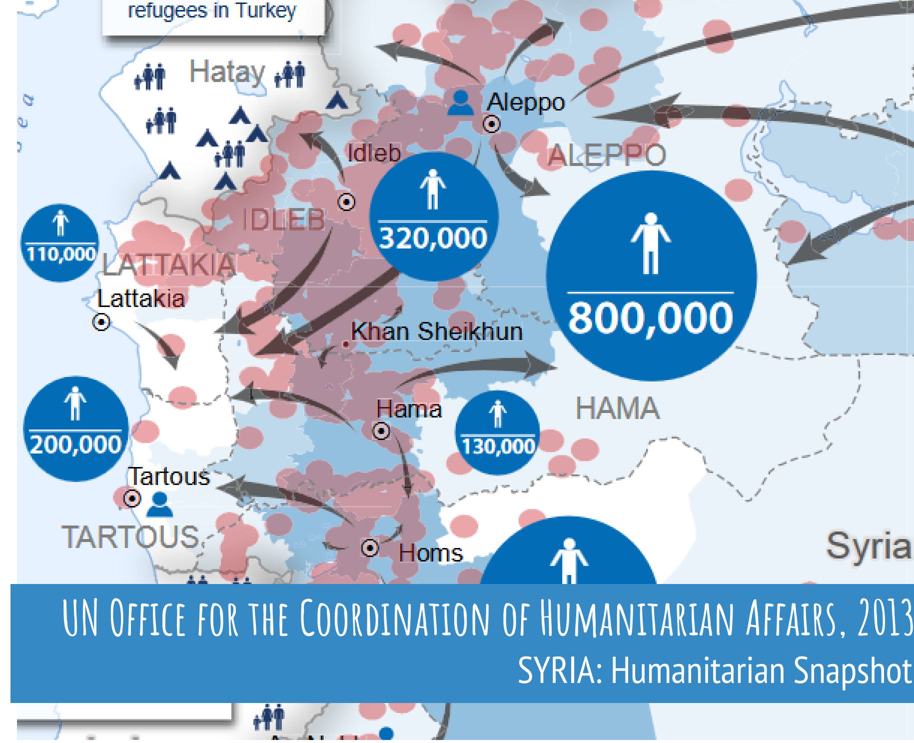
Ana Kuveždić Divjak, Boško Pribičević, Almin Đapo

University of Zagreb, Faculty of Geodesy



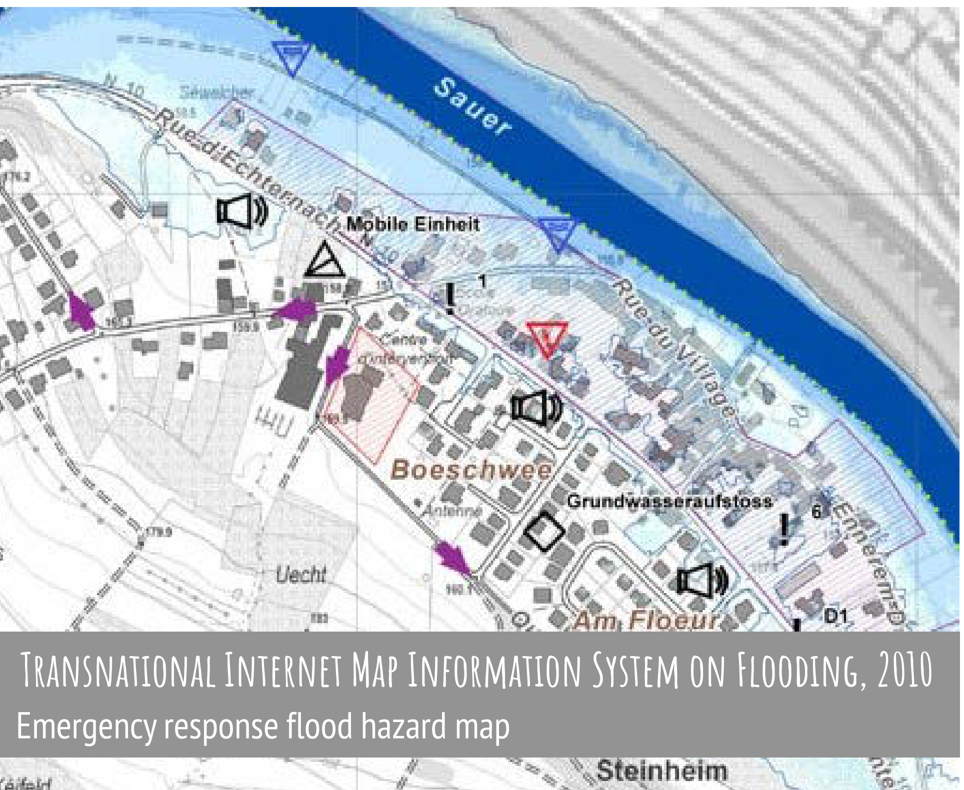
Geneva International Centre for Humanitarian Demining, 2005

Map Symbols in the Information Management System for Mine Action



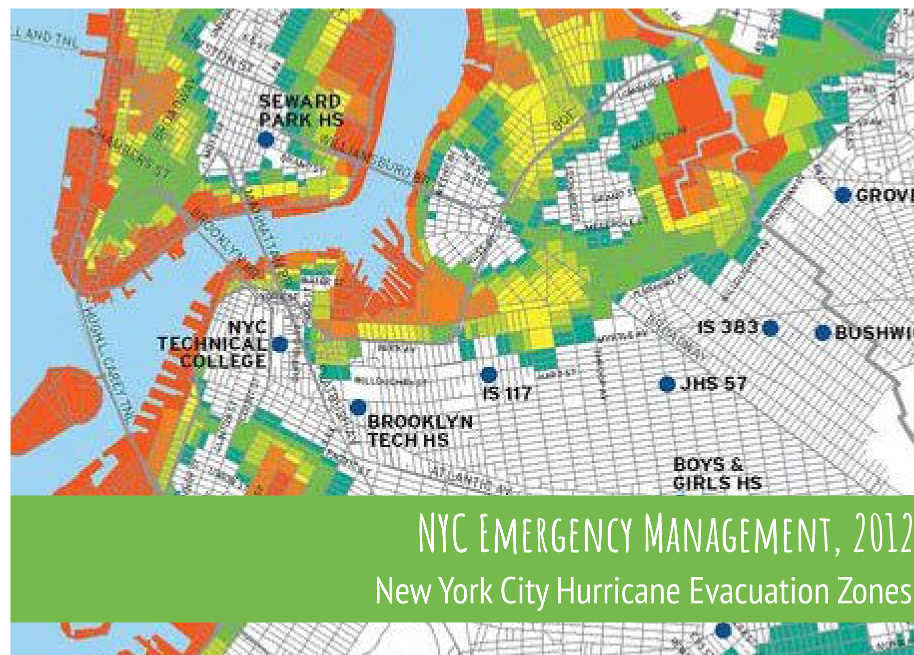
UN Office for the Coordination of Humanitarian Affairs, 2013

SYRIA: Humanitarian Snapshot



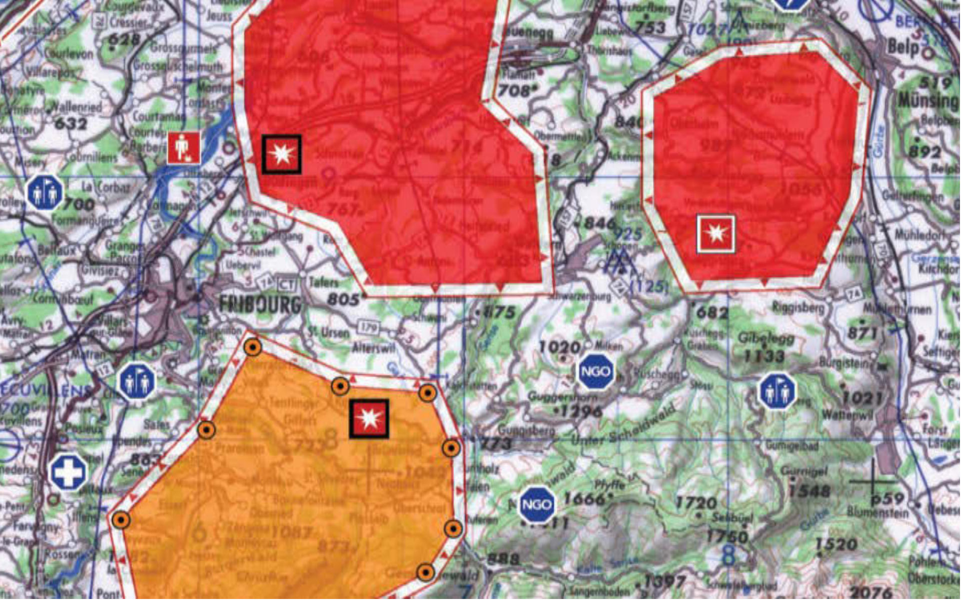
Transnational Internet Map Information System on Flooding, 2010

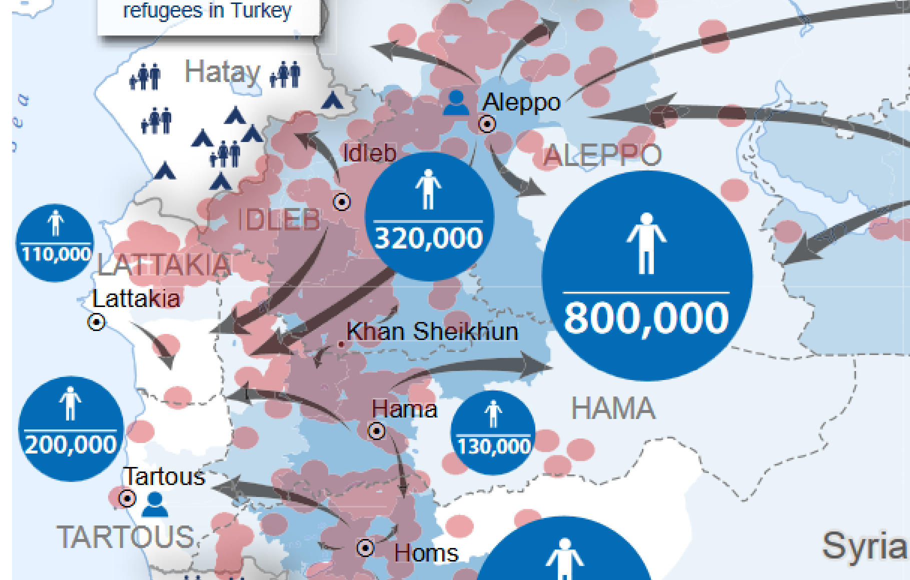
Emergency response flood hazard map



NYC Emergency Management, 2012

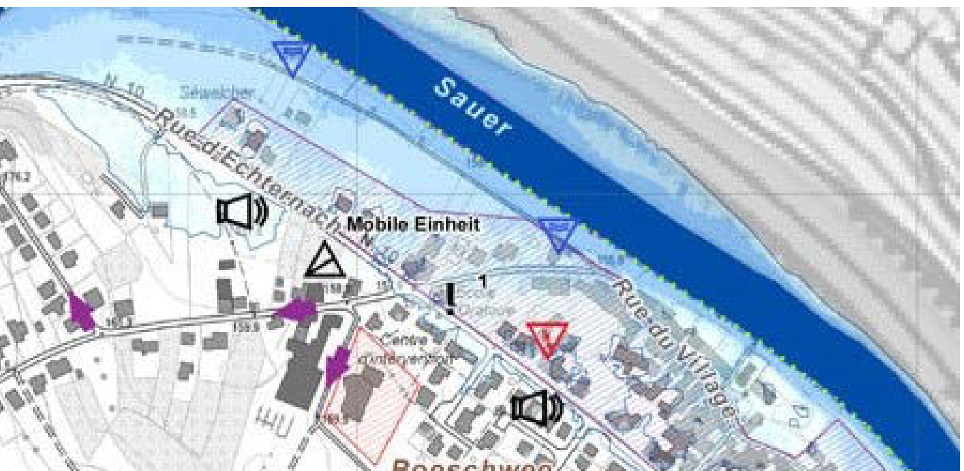
New York City Hurricane Evacuation Zones



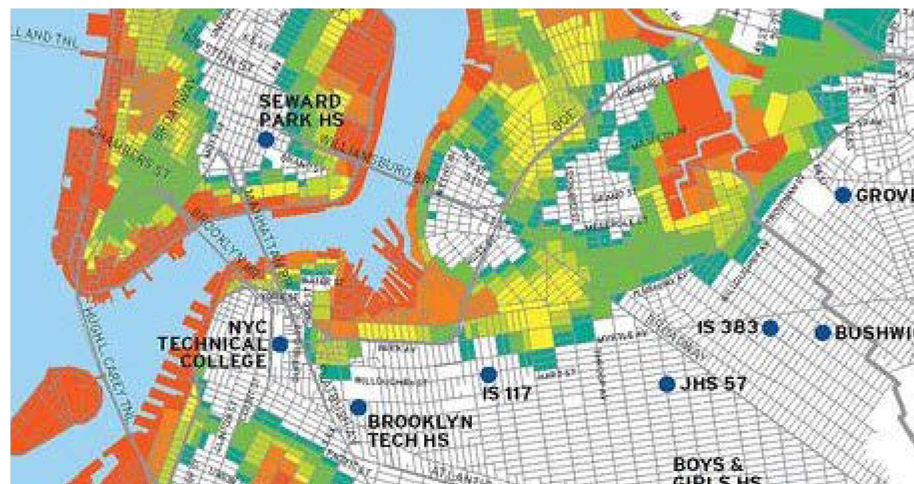


UN Office for the Coordination of Humanitarian Affairs, 2013

SYRIA: Humanitarian Snapshot

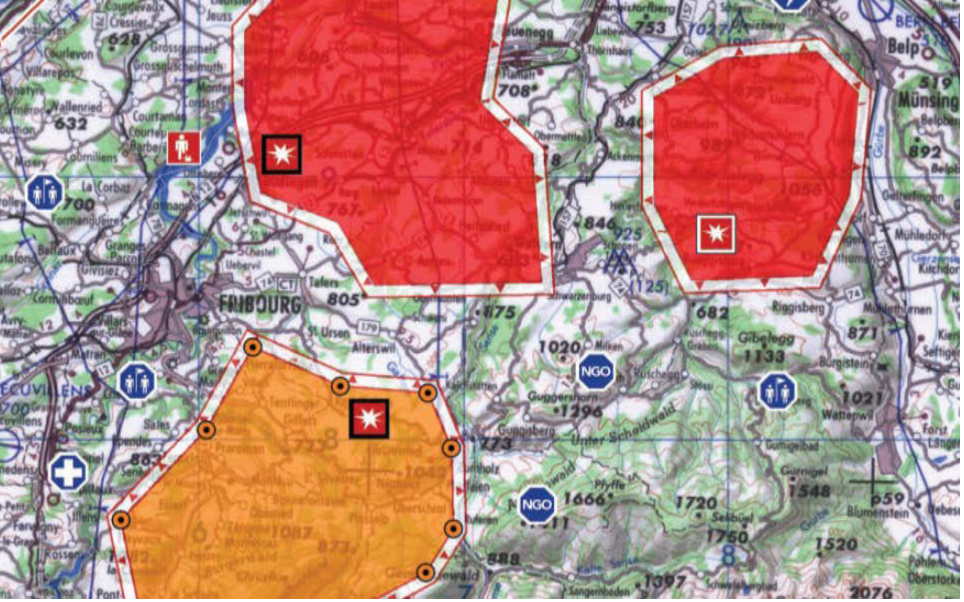


The aim of symbology for many crisis cartographic visualisations are simple, clear, aesthetically pleasing symbols that can be easily used and understood by a wide range of crisis map users.

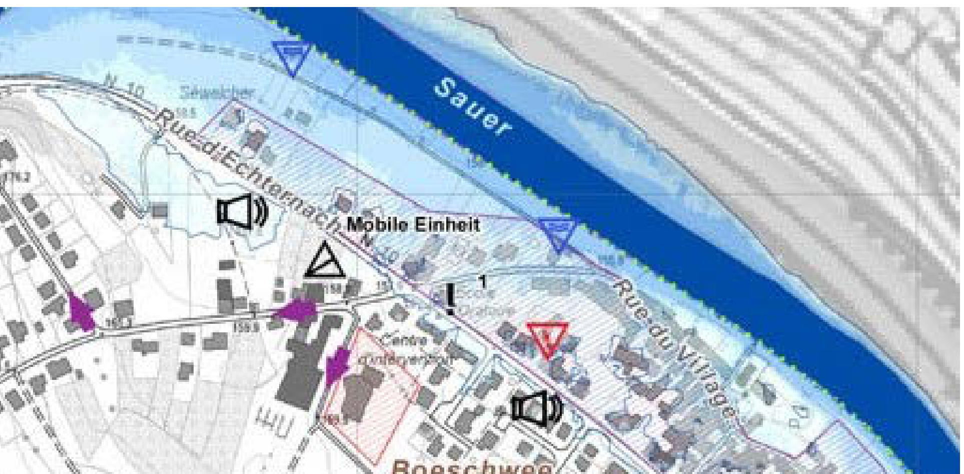


NYC Emergency Management, 2012

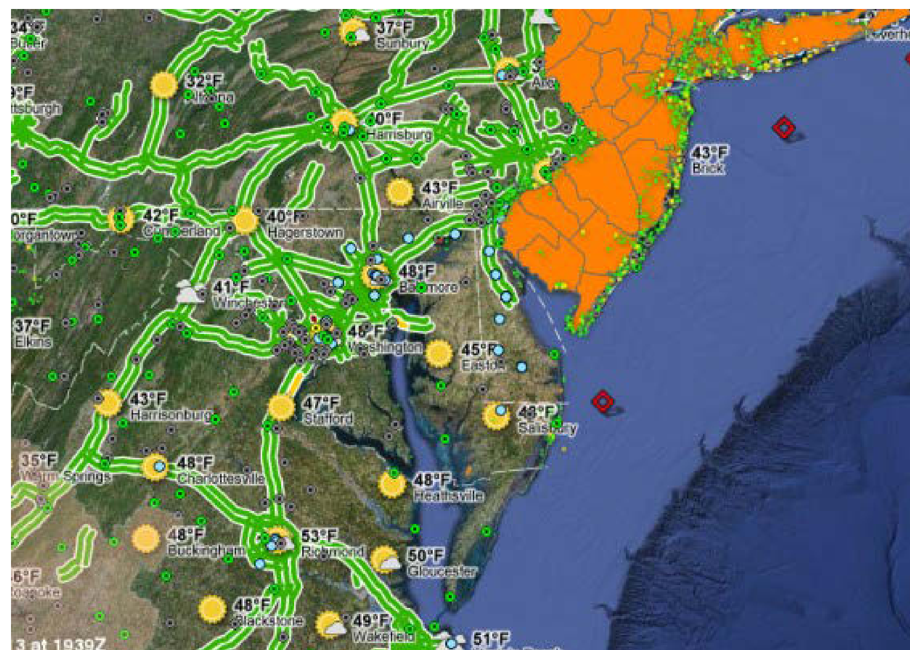
New York City Hurricane Evacuation Zones



If they are incomprehensible, illegible, ambiguous, unclassified, and random, if they lack hierarchical organisation, they can fail to deliver the intended message.



The aim of symbology for many crisis cartographic visualisations are simple, clear, aesthetically pleasing symbols that can be easily used and understood by a wide range of crisis map users.

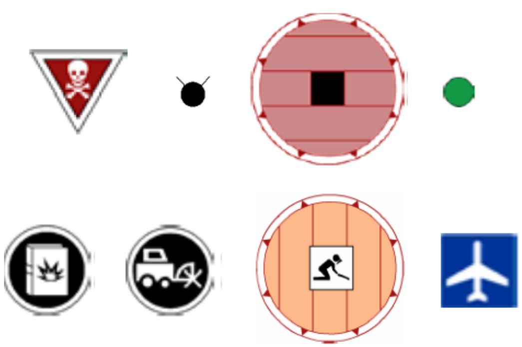


CRISIS MAP SYMBOLOGY

Emergency Response Symbology
(HSWG, FGDC, USA, 2005)

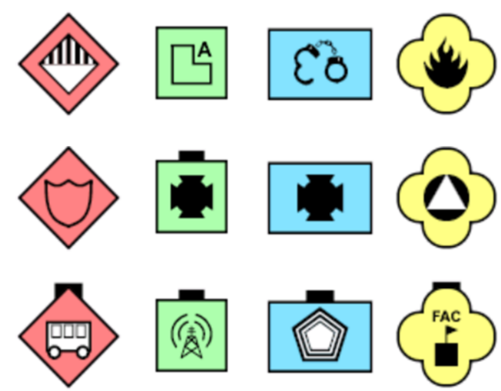
Canadian All-Hazards Symbology
For Emergency Management
(GOC, Canada, 2015)

Australian All Hazards Symbology
(EMSINA, Australia, 2007)



Humanitarian Demining Symbols
(GICHD, 2005)

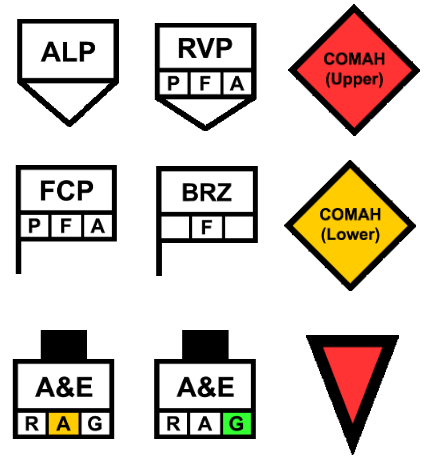
OCHA's Humanitarian Icons
(UN OCHA, International, 2012)



MIL-STD-2525D
(Department of Defense, USA, 2008)

CRISIS
MAP SYMBOLOGY

European Emergency Symbology reference for 2D/3D maps (INDIGO project, Europe, 2012)



Civil Protection Common Map Symbology (Ordnance Survey, UK, 2012)

Symbol System for DM (Laboratory on Cartography, Sofia University of Architecture, Civil Engineering and Geodesy, 2017, Bulgaria)

CRISIS
MAP SYMBOLOGY

Challanges:

Design issues
Symbol taxonomies
Standardisation
Sharing and promulgation

After:
Kostelnick, J. and Hoeniges, L. (2018):
Map Symbols for Crisis Mapping:
Challenges and Prospects.
The Cartographic Journal. 56. 1–14.

COMPARATIVE ANALYSIS OF CRISIS MAP SYMBOLOGY

Matherials and Methods:

- 6 prominent examples of symbol sets that were promoted in the cartographic scientific and crisis mapping community in recent years

CRISIS MAP SYMBOLOGY

Challanges:

Design issues
Symbol taxonomies
Standardisation
Sharing and promulgation

After:
Kostelnick, J. and Hoeniges, L. (2018): Map Symbols for Crisis Mapping: Challenges and Prospects. The Cartographic Journal. 56. 1–14.

Research questions:

- Crisis symbology sets available for use?
- Is the set updated? Has it been re-edited? Changes implemented?

CRISIS MAP SYMBOLOGY

Challanges:

Design issues
Symbol taxonomies
Standardisation
Sharing and promulgation

After:
Kostelnick, J. and Hoeniges, L. (2018): Map Symbols for Crisis Mapping: Challenges and Prospects. The Cartographic Journal. 56. 1–14.

- Crisis symbology sets available for use?
- Taxonomy of cartographic symbols in sets and their internal breakdown? Graphical variables used to support visual and cognitive organisation?

Research questions:

- Is the set updated? Has it been re-edited? Changes implemented?

CRISIS MAP SYMBOLOGY

Challanges:

Design issues
Symbol taxonomies
Standardisation
Sharing and promulgation

After:
Kostelnick, J. and Hoeniges, L. (2018): Map Symbols for Crisis Mapping: Challenges and Prospects. The Cartographic Journal. 56. 1–14.

- Crisis symbology sets available for use?
- Taxonomy of cartographic symbols in sets and their internal breakdown? Graphical variables used to support visual and cognitive organisation?
- Measures for general and repeated use? Expansion with additional symbols? Guidelines? Assessment of the design, efficiency, and recognition?

Research questions:

- Is the set updated? Has it been re-edited? Changes implemented?

CRISIS MAP SYMBOLOGY

Challanges:

Design issues
Symbol taxonomies
Standardisation
Sharing and promulgation

After:
Kostelnick, J. and Hoeniges, L. (2018): Map Symbols for Crisis Mapping: Challenges and Prospects. The Cartographic Journal. 56. 1–14.

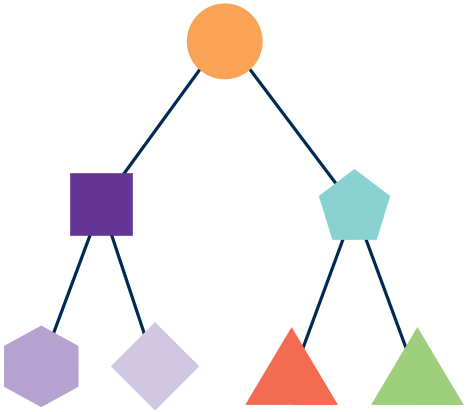
Research questions:

- Crisis symbology sets available for use?
- Taxonomy of cartographic symbols in sets and their internal breakdown? Graphical variables used to support visual and cognitive organisation?
- Measures for general and repeated use? Expansion with additional symbols? Guidelines? Assessment of the design, efficiency, and recognition?
- How do we know the symbol set exists? Format for sharing? Promotion? Materials available (such as examples of the use of map symbols, manuals for their use, “best practices” guidelines)?
- Is the set updated? Has it been re-edited? Changes implemented?

COMPARATIVE ANALYSIS OF CRISIS MAP SYMBOLOGY

Taxonomy, Visual and Hierarchical Organisation

- Taxonomy – the division that categorises the objects, phenomena, and action for display on crisis maps and organised them into groups based on their similarity and difference
- How was the thematic organisation into categories transfered into the graphical appearance of the symbols, i.e. which graphic variables (e.g. colour, shape, size, etc.) were used?

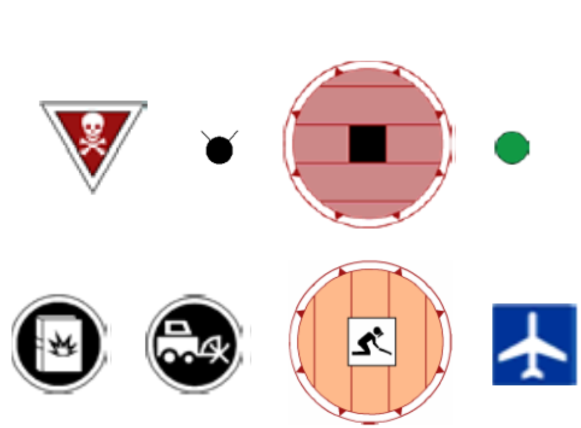


Emergency Response Symbology
(HSWG, FGDC, USA, 2005)

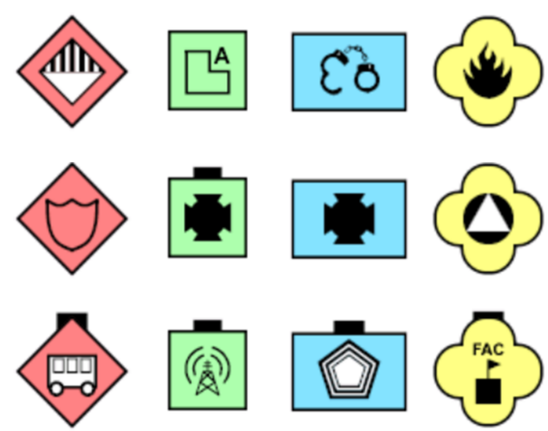
Canadian All-Hazards Symbology
For Emergency Management
(GOC, Canada, 2015)

Australian All Hazards Symbology
(EMSINA, Australia, 2007)

OCHA's Humanitarian Icons
(UN OCHA, International, 2012)



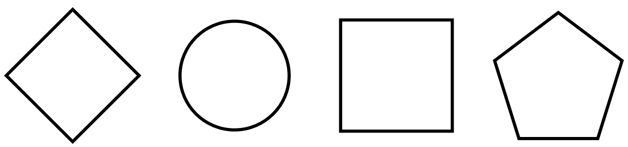
Humanitarian Demining Symbols
(GICHD, 2005)



MIL-STD-2525D
(Department of Defense, USA, 2008)

COMPARATIVE ANALYSIS OF CRISIS MAP SYMBOLOGY

Taxonomy, Visual and Hierarchical Organisation



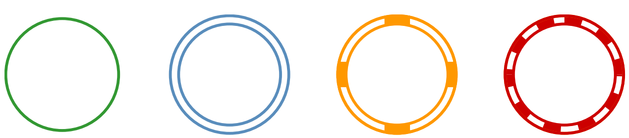
Thematic and visual organisation

(Emergency Response Symbology, Canadian All-Hazards Symbology and Australian All Hazard Symbology)

Ordered property

for representing the status of the asset within the symbol

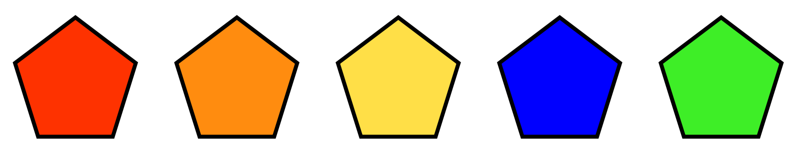
(Australian All Hazard Symbology)



Visual hierarchical status

on the damage and operational level

(Emergency Response Symbology)



Selective property

a scale of colours of the same brightness for additional selective emphasis of the features effected

(Australian All Hazard Symbology)

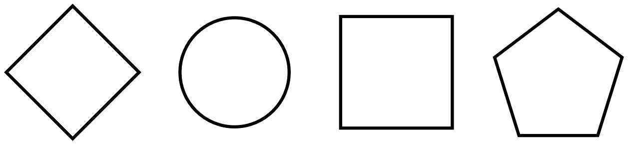
COMPARATIVE ANALYSIS OF CRISIS MAP SYMBOLOGY

Taxonomy, Visual and Hierarchical Organisation

- Ordered property
  not present in the first versions but was included in second editions of the sets *Australian All Hazards Symbology* and *Canadian All Hazards Symbology*

COMPARATIVE ANALYSIS OF CRISIS MAP SYMBOLOGY

Taxonomy, Visual and Hierarchical Organisation



Thematic and visual organisation

(Emergency Response Symbology, Canadian All-Hazards Symbology and Australian All Hazard Symbology)

(OCHA's Humanitarian Icons)

(Humanitarian Demining Map Symbols)

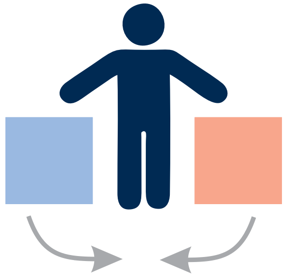
Thematic organisation

not transferred into the visual appearance of the symbols, associative and selective properties of cartographic symbols were not achieved

COMPARATIVE ANALYSIS OF CRISIS MAP SYMBOLOGY

Availability (Sharing, Dissemination and Promulgation)

- Symbols are most commonly shared via the organisation's website in different proprietary formats (raster PNG and vector SVG format)
- Technical resources also included predefined style files for ESRI's ArcGIS for all analysed symbol sets and for QGIS (in the case of OCHA's Humanitarian Icons and Australian All Hazards Symbology)
- The OCHA's Humanitarian Icons are available in The Noun Project, Emergency Response Symbology set are built-in in Symbol Store
- Joint Military Symbology XML (JointMilSyML or JMSML) is an XML schema, and associated instance data, designed to document the contents of MIL-STD 2525D

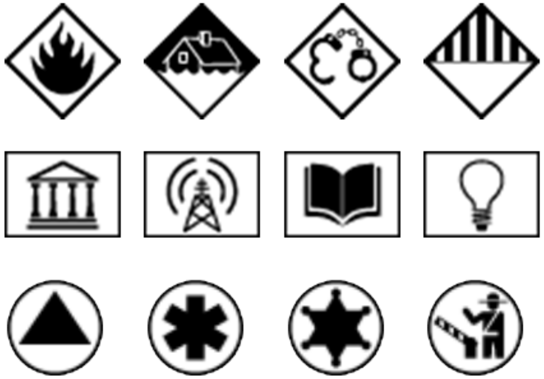


COMPARATIVE ANALYSIS OF CRISIS MAP SYMBOLOGY

Standardisation (General and Repeated Use)

- Tradition, homogeneity, uniformity, and standardisation both in the graphic design of symbols and in their application on crisis maps

- American National Standards Institute (ANSI) standard



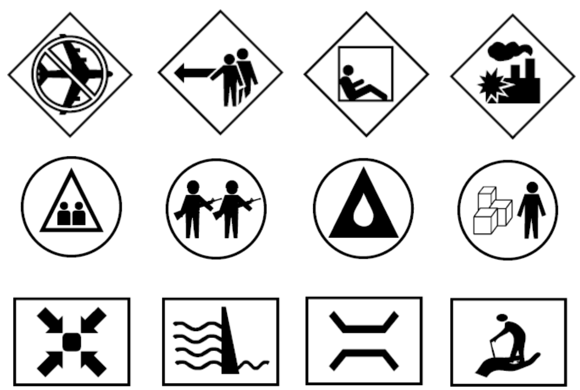
Emergency Response Symbology
(HSWG, FGDC, USA, 2005)

COMPARATIVE ANALYSIS OF CRISIS MAP SYMBOLOGY

Standardisation (General and Repeated Use)

- Tradition, homogeneity, uniformity, and standardisation both in the graphic design of symbols and in their application on crisis maps
- American National Standards Institute (ANSI) standard

Emergency Response Symbology
(HSWG, FGDC, USA, 2005)



Canadian All-Hazards Symbology
For Emergency Management
(GOC, Canada, 2015)

Australian All Hazards Symbology
(EMSINA, Australia, 2007)

COMPARATIVE ANALYSIS OF CRISIS MAP SYMBOLOGY

Standardisation (General and Repeated Use)

- Standardisation of Usage
  mostly general, more detailed guidelines and rules for proper application of cartographic symbols on crisis maps have not been found

COMPARATIVE ANALYSIS OF CRISIS MAP SYMBOLOGY

Standardisation (General and Repeated Use)

- Extension of the Set with New Symbols
  guidelines for extending the existing set with new symbols are not publicly available

  Australian All Hazard Symbology → dedicated symbology officer, workflow for new Symbology proposals clearly stated

Standardisation (General and Repeated Use)

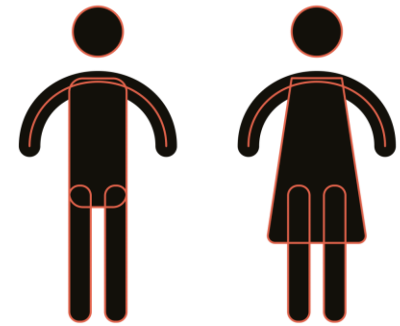
- Extension of the Set with New Symbols
  guidelines for extending the existing set with new symbols are not publicly available

  OCHA's Humanitarian Icons (exception!) → effort to standardise the guidelines for extending the existing set with new symbols
  OCHA Graphics Stylebook (UN OCHA, 2018)

INTRODUCTION

These guidelines will give you some basic guidance on how to create humanitarian icons. The guidelines are not intended to be restrictive or to limit creativity; they are simply to help establish some rules for all designers so that there is consistency across the icon family.

Humanitarian icons can always be modified and adapted to a specific context. Their use is not mandatory.



NO 3D/PERSPECTIVE

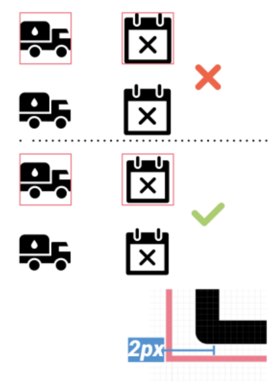
As a general rule, design in 2D (flat), unless it is necessary to understand the concept.

BALANCE SIZES

When the shape is very close to a square and is filling most of the area, add at least 2 pixels of the inner margin to balance the size with the rest of the icons. Otherwise the icon will look huge next to those with a more rectangular shape.

This is one of the most subjective and difficult parts of the icon-design process. It depends on the 'eye of the designer', but it's very important in order to make icons work properly together.

To balance sizes, put several icons with different shapes together. You will see which one needs an inner margin to compensate. Typically about 2-5 pixels inner margin is needed for certain icons.



Standardisation (General and Repeated Use)

- Assessment

  Assessing the symbol design and recognisability from the *Emergency Response Symbology* set was conducted (by the Homeland Security Working Group in 2004, and in an on-line open-type survey in which various crisis management and emergency services volunteers participated)

  Assessment of the symbol design of the *Humanitarian Demining Map Symbols* was conducted when the symbols were in the initial version by professional pyrotechnicians

CONCLUSION

Comparative analysis of:

- 6 prominent examples of symbol sets that were promoted in the cartographic scientific and crisis mapping community in recent years

CONCLUSION

Comparative analysis of:

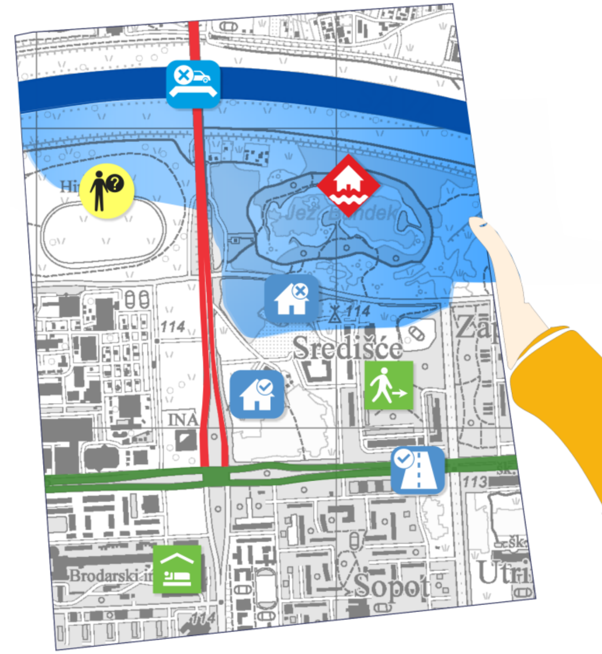
- 6 prominent examples of symbol sets that were promoted in the cartographic scientific and crisis mapping community in recent years

➡ Results:

- certain changes were implemented in new, reviewed or extended editions of existing sets
- assistance to less unified and coherent standards and symbologies currently in use

THANK YOU FOR YOUR ATTENTION!

Ana Kuveždić Divjak
akuvezdic@geof.hr
Faculty of Geodesy, University of Zagreb



This work has been fully supported by the Croatian Science Foundation under the project number IP-01-2018-8944.

The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-3/W8, 2019
Gi4DM 2019 – GeoInformation for Disaster Management, 3–6 September 2019, Prague, Czech Republic

GEOINFORMATION FOR RESEARCH OF ONGOING GEODYNAMIC PROCESSES IN THE REPUBLIC OF CROATIA

A. Kuveždić Divjak [1*], M. Govorčin [1], B. Matoš [2], A. Đapo [1], J. Stipčević [3], B. Pribičević [1]

[1] Faculty of Geodesy, University of Zagreb, Zagreb, Croatia; - (akuvezdic, mgovorcin, adapo, bpribic)@geof.hr
[2] Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia - bmatos@rgn.hr
[3] Department of Geophysics, Faculty of Science, University of Zagreb, Zagreb, Croatia - jstipcevic@gfz.hr

Commission VI, WG VI/4

KEY WORDS: geoinformation, geodynamic processes, geodetic data, geological data, seismological data, integrated use

ABSTRACT:

Multidisciplinary research of surface geodynamic processes is important for understanding mechanisms that lead to sudden release of accumulated strain energy, i.e. earthquakes. It requires development of an original scientific approach which combines data from various geosciences such as geodesy, geology and seismology. This implies that each geoscience contributes to a better understanding by providing specific direct or indirect information on activity (spatial movements) and properties of seismogenic sources (faults). In recent years, new and accessible sources and types of geoinformation have greatly enhanced, enabling a more comprehensive investigation of ongoing geodynamic activity on faults and, therefore, improve our ability to develop approaches to assess and mitigate the seismic hazard and risk within the earthquake-prone areas.

In this paper, we seek to identify the geoinformation required to improve the current knowledge on regional and local geodynamic processes in the Republic of Croatia. Focusing on the complementarity of geodetic, geological and seismological data, we discuss possible sources of the diverse sets of site-specific geospatial data. Examples include: ground/surface movement observations with Global Navigational Satellite Systems (GNSS) and Satellite Radar Interferometry (InSAR); data about historical and instrumental seismicity (e.g. focal mechanism solutions, number of earthquakes, b-value, etc.); fault location, fault geometrical properties and information on their neotectonic activity, paleoseismological data, etc. Challenges regarding the integrated use of these data, such as heterogeneity of data sources, access protocols, metadata standards, data quality, up-to-dateness, and other limitations are also addressed.

1. INTRODUCTION

Geodynamics deals with the processes occurring in the Earth's interior, particularly as regards their effects on the crust and its superficial zone. Research and monitoring of surface geodynamic processes is important for understanding of the mechanisms that lead to seismic activity, i.e. earthquakes. It requires an interdisciplinary approach of various geosciences such as geodesy, geology, and geophysics (seismology), where each discipline contributes with a specific set of measurements in order to get broad understanding of the geodynamic processes.

Geospatial technologies provide capabilities for data collection, processing, analysis, and visualization that are essential in all phases of the geodynamic research. In its initial phase, the research activities that investigate accumulation and release of seismic energy, i.e., earthquakes are mainly associated to geological and seismological research methods. Geological methods are primarily based on the analysis of geological and geophysical data with the objectives of defining timing of structure evolution, structural-geological relationships, identification of principal discontinuities i.e., faults in a research area. On the other hand, seismology and seismotectonics are focused on determination of kinematic properties of active faults, as well as their geometrical parameters, which are crucial in definition of fault's seismic potential. Seismological methods are focused on studying historical and instrumental seismic activity in the research area, with the principal objectives of better defining the seismic hazard, characterization of stress distribution and tectonic processes.

With the development of modern geodetic satellite methods for spatial data collection, the role of geodesy in geodynamic research has gained much importance. Geodesy enables the collection of geometric information on the distribution of Earth's stress and strain on the global, regional and local level through observations in exclusive time period with respect to reference frame. For this reason, geodetic research represents an ideal addition to geological and seismological results when examining and characterizing recent tectonic movements in the research area.

The Republic of Croatia is situated in a collision zone that is part of the Mediterranean convergence zone, a collision zone between the African and Eurasian tectonic plates (e.g., Tari, 2002; Schmid et al., 2008 with references). Based on the previous research, the largest portion of geodynamic movements within the Dinaridic fold-thrust belt and SW Pannonian Basin have been linked to dynamics and kinematics of the Adria microplate that moves independently in respect to the African and Eurasian tectonic plates (D'Agostino et al., 2008 with references). Convergence of the Adria microplate and

* Corresponding author

https://doi.org/10.5194/isprs-archives-XLII-3-W8-233-2019 |

stable Eurasian plate (2-5 mm/yr., e.g., Grenerczy et al., 2005; Bennett et al., 2008; Weber et al., 2010) is reflected through strain accumulation and distribution of tectonic activity along the margins of the Adria microplate, which is due to differential stress distribution in the Earth's crust accompanied by seismic activity, i.e. earthquakes. Tectonic activity is also manifested through heterogeneous distribution of stresses in the Earth's crust, which leads to seismic activity along neotectonic active faults i.e. reverse and/or strike-slip faults mapped within the research area. Recent geodynamic processes that manifest through ongoing seismic activity represent a potential risk for the population living in the area. This implies occurrence of earthquakes that may yield instantaneous release of accumulated seismic energy causing material and non-material damage, and potential human casualties. Geodynamic and kinematic processes are not restricted to national boundaries, so understanding the cause-and-effect relationships is of great importance for the safety of the local community, and for society in the wider area.

In this paper we report possible sources of geoinformation that could be used to address the current knowledge on ongoing geodynamic processes in the Republic of Croatia. We refer to the term geoinformation in its general sense, as the collection and storage of georeferenced data that can be queried by both, attribute and location. We first describe the sources of site-specific geospatial data for each of the contributing geoscience disciplines, giving the scale, precision, and usage to which they were applied. Focusing on the complementarity of geodetic, geological and seismological data, we complete the paper with the discussion of challenges regarding their integrated use, such as heterogeneity of data sources, access protocols, data standards, data quality, up-to-dateness and other limitations.

2. GEOINFORMATION FOR RESEARCH AND MONITORING OF GEODYNAMIC PROCESSES

2.1 Geodesy

A range of techniques exist in geodesy to measure the crustal deformations that are associated with plate motion and active faults. The examples include: traditional, ground-based optical or mechanical methods, such as triangulation, trilateration, and levelling, as well as a number of space-based techniques of which Very Long Baseline Interferometry (VLBI), the Global Navigational Satellite System (GNSS) and Interferometric Synthetic Aperture Radar (InSAR) have imposed as the most significant (Burgmann, Thatcher, 2013).

Geodetic research at the global and regional level are focused on tracking geodynamic processes related to tectonics by conducting observations on the global, continental, and regional networks (such as the International GNSS Service (IGS) or EUREF Permanent Network (EPN)) using the Global Navigational Satellite System (GNSS) (Kreemer et al., 2014), and the long-distance interferometry for a certain period (Jordan, Minster, 1988; Cambell, Nothnagel, 2000).

The geodetic methods most commonly used to collect spatial data on temporal development of surface deformations of the Earth's crust on the local level, i.e. the narrower area around fault zones, are the GNSS networks (Murray-Moraleda, 2009), and the Interferometric Synthetic Aperture Radar (InSAR) (Massonnet, Feigl, 1998). Geodetic methods at the local level provide a very good basis for monitoring seismic cycles on seismogenic sources, starting from inter-seismic phase (stress accumulation process, i.e. ground deformations that precede earthquake), to coseismic phase (ground and surface displacements caused by earthquake released energy) and postseismic phase (ground and surface deformations after earthquake event).

2.1.1 GNSS Data for Crustal Deformation Studies

GNSS tracks a relative three-dimensional position of thousands of campaign-mode and continuously operating stations with sub-centimetre precision (Burgmann, Thatcher, 2013). A number of research papers can be found that provide more detailed introductions into the crustal deformation research with GNSS carried out along plate boundaries all over the world, revealing the complex and variable patterns of the shifting plates and the complex deformation at their boundaries (e.g., see Burgmann, Thatcher, 2013 with references). Rather than attempt to comprehensively review this body of work, we focus here on the brief description of the method and representative results of geodynamic studies employing GNSS observations carried out in Croatia in the last 30 years.

The use of GNSS technique for geodynamic investigations depends on the configuration and the size of the GNSS network, which define the achievable spatial resolution of the ground displacements. The network consists of specially stabilized monuments for installation of GNSS receivers distributed in accordance with the network application (from global, regional to local scale). Frequency of GNSS observations on the network defines the temporal resolution of ground displacements, which can obtained either with continuous (permanent) GNSS (cGNSS) or campaign mode (episodic) GNSS observations. .

GNSS campaign-mode observations are series of repeated measurement campaigns on the network within certain time intervals. Repeating this procedure at different time intervals (e.g. every year) provides the necessary kinematic information of ground deformation field. To acquire sub-centimetre precision of ground displacement detection necessary for most crustal deformation studies, it is recommended to perform GNSS campaigns on the network once per year at the same season for a minimum time-span of 3 years (in order to mitigate seasonal noise in data). On the other hand, continuous GNSS observations work in real-time, acquiring a large amount of data that result in a high temporal resolution and precision of obtained ground displacements. Minimum time-span of GNSS observations on the network needed to mitigate seasonal position variation in the data is considered to be 2.5 years (Blewitt and Lavallee 2002). We consider maximum achievable precision of GNSS measurements with GNSS campaigns after 10 years to be in range of ~1.5 mm/yr due to systematic errors related to antenna offset, whereas cGNSS can achieve 0.2 mm/yr and 0.4 mm/yr horizontal and vertical precision, respectively (Akarsu et al., 2015). GNSS observations result in the three-dimensional velocity field and time series data of the observed area relative to used reference frame for the observed time period.

Several international geodynamic projects have been carried out in Croatia for the past three decades in a form of GNSS campaigns. The most prominent examples include: *Central European Geodynamics Project* CERGOP (carried out in two stages 1994–1999 and 2001–2006) (Medak et al., 2002), *Croatian geodinamyc project* CRODYN (in 1994, 1996, 1998 and 2013) (Marjanović, 2008; Pavasović 2014), *Croatian Reference GPS campaign* CROREF95, 96, and 2005, *Retreating-Trench, Extension and Accretion Tectonics Project* RTREAT (Marjanović, 2008; Pavasović, 2014; Pavasović et al. 2015). There were altogether 21 GPS campaigns with the purpose of determining geodynamic movements on the Croatian territory, all carried out with 24-hour measurement sessions on each point, processed in Bernese software and resulted with velocity models for the research area (Pavasović, 2014). Furthermore, in geodynamic research of potential recently-active fault zones on the territory of Croatia, it is important to mention the project *Geodynamic GPS Network of the City of Zagreb*, which has been active since 1997 until today (Pribičević et al., 2016). Results of the aforementioned projects are relative velocity fields available only in a form of scientific publication.

In terms of cGNSS results, the usage of CROPOS network for determination of Adria microplate geokinematic model can be found in (Pavasović, 2014). CROatian POsitioning System – CROPOS is national network of 33 referential permanent GNSS stations covering the entire Croatian territory since 2008. The baseline length between stations is approx. 70 km. GNSS data is provided through geodetic precise positioning service (GPPS) as receiver independent exchange format (RINEX) via CROPOS RINEX web-shop. Responsible organisation is the State Geodetic Administration of the Republic of Croatia (URL1). Other available sources of cGNSS results on the territory of Croatia are derived velocity and time series solutions on EUREF network provided as position solutions (SINEX format) (see Table 1) based on five EPN permanent stations located on the Croatian territory: CAKO00HRV (Čakovec), POZE00HRV (Požega), PORE00HRV (Poreč), ZADA00HRV (Zadar) and DUB200HRV (Dubrovnik).

For future crustal deformation studies on the Croatian territory, it is also important to identify stations of other GNSS networks in the region: Italy – RING (URL2), Slovenia – Signal (URL3), Hungary – GNSSnet.hu (URL4), Federation Bosnia and Hercegovina – FBiHPOS (URL5), Republika Srpska SRPOS (URL6) and Montenegro – MontePOS (URL7).

2.1.2 InSAR for Global and Dense Remote Sensing of Deformation

Satellite radar interferometry (InSAR) proves to be a very useful remote sensing technique for investigation and monitoring of surface displacements caused by geodynamical processes. The technique is based on the measurement of angular difference in phase information of returned electromagnetic signals over the same area received by spaceborne Synthetic Aperture Radar (SAR) at two distinct times. The result is interferogram, an image of phase differences that contain information on surface displacements in line-of- sight direction, towards or away from the satellite. More on the SAR acquisition principles and interferogram generation can be found in (Hanssen, 2011). Major advantages of the technique are high spatial resolution (~100 pixels/km2), competitive precision (~1cm) and temporal acquisition frequency (1 acquisition per month, or every 6 days nowadays) of ground displacement observations anywhere around the globe (Massonnet, Kiegl, 1998). Since the first mapping demonstration of surface deformation caused by the Landers earthquake in 1992 (Massonnet et al., 1993), InSAR technique has been widely used for investigation of coseismic ground deformations caused by earthquake rupture (Pedersen et al., 2001; Jonsson et al., 2002; Wright et al., 2003; Stramondo et al., 2005; Motagh et al., 2008; Atzori et al., 2009; Kaneko et al., 2015; Nissen et al., 2016).

The applicability of conventional InSAR technique is constrained with several sources of error; phase decorrelation, atmospheric phase delay, inaccurate topographic model and imprecise satellite orbits. The latter technique's limitations were overcome with development of multi-temporal InSAR techniques: Persistent Scatterers (PS-InSAR) (Ferreti et al., 2001) and Small Baseline (SBAS) (Berardino et al., 2002). By connecting multiple interferograms in one data stack, coherent phase differences temporal and spatial characteristics can be exploited to model the aforementioned sources of errors and develop temporal evolution of surface displacements. The result is a relative line-of-sight velocity field with a precision of a few millimetres (~1-3 mm/yr Fattahi, Amelung, 2014; Marinković et al., 2008) and high spatial resolution (~10 000–100 000 per km^2). Overview of key differences between two MT-InSAR techniques and algorithms in use can be found in (Osmanoglu et al., 2016). Ability to develop temporal evolution of surface displacements together with time-series analysis enable InSAR technique to be used for investigation of interseismic (Cakir et al., 2014; Bekaert et al., 2015; Chaussard et al., 2016; Hussain et al., 2018) and postseismic (Arnadottir et al., 2005; ElGharbawi, Tamura, 2015; Wang, Fialko, 2018; Feng et al., 2018) ground deformations.

In the Republic of Croatia, InSAR technique was applied for investigation of interseismic ground deformations over the wider Zagreb area (NW Croatia) and coseismic ground deformation of Ston-Slano 1996 ML 6.0 earthquake (SE Croatia). The conventional InSAR technique was applied to determine coseismic ground deformations caused by the Ston-Slano ML 6.0 earthquake occurred in Dubrovnik County on September 05, 1996 (Govorčin et al., 2018). The technique was applied on two ERS2 satellite images acquired from descending track, one image that predates (August 09, 1996) and one after (July 25, 1997) the earthquake event, and resulted in a coseismic interferogram (Govorčin et al., 2018). Persistent Scatterers MT-InSAR technique was applied though the project *The Geodynamic GPS Network of the City of Zagreb* to characterize ongoing interseismic ground deformations over the wider Zagreb area in 2015. The MT-InSAR techniques resulted in two relative velocity fields (~135 000 points) of the wider Zagreb area in the period 2004–2009. Used data in the processing were 40 Envisat-ASAR images acquired from ascending and descending orbit over the area (Pribičević et al., 2017). Final products (interferograms and velocity fields) of the aforementioned InSAR applications are available only as the cited publications. Available InSAR final products over Croatian territory can be found at COMET-LiCS Sentinel-1 InSAR portal (URL8). COMET-LiCS provides Sentinel-1 generated interferograms covering Himalayan Belt and East African Rift, available via the EU Infrastructure project EPOS (see Table 1).

https://doi.org/10.5194/isprs-archives-XLII-3-W8-233-2019 | © Authors 2019. CC BY 4.0 License.

Source title	**EUREF Permanent Network (EPN), station positions and velocities**	**Geological Maps of the Republic of Croatia**	**The European Database of Seismogenic Faults (EDSF)**	**Croatian Earthquake Catalogue (CEC)**	**SHARE European Earthquake Catalogue (SHEEC) 1000-1899**	**Croatian Earthquake Hazard Maps**	**COMET-LiCS Sentinel-1 InSAR Portal**
Description	A science-driven network of permanent GNSS tracking stations whose weekly computed positions are used by EUREF to realize the European Terrestrial Reference System (ETRS89).	Official geological maps of the Republic of Croatia at the scale of 1:50 000, 1:100 000 and 1:300 000	EDSF includes only faults that are identified and mapped as neotectonics active faults, i.e., possible seismogenic sources capable of generating earthquakes of magnitude equal to or larger than 5.5. It aims to ensure a homogeneous input for use in ground-shaking hazard assessment in the Euro-Mediterranean area.	CEC is the main database about the past and present earthquakes in Croatia covering period from 373 BC until today compiled using all data on earthquakes from the archives of the Department of Geophysics, Faculty of Science, University of Zagreb (the catalogues, macroseismic reports, seismograms, and other related documents).	SHEEC is a European parametric earthquake catalogue, as much homogeneous as possible, which covers the time window 1000–1899. Developed within the frame of the European Commission project SHARE compiled from European Archive of Historical EArthquake Data.	Maps of seismic hazard in Croatia expressed by the probability of exceedance of PGA for return periods of 475 years and 95 years.	Online Catalog of Sentinel-1 generated interferograms and coherence maps. Results are available for download as Derived Works of Copernicus data (2015–2016) through interactive online map. Products are: Unfiltered wrapped phase (Quicklook, Magnitude, Phase), Coherence (Quicklook, Phase) and filtered unwrapped phase (quicklook, unwrapped interferogram)
Responsible organization	IAG (International Association of Geodesy) Regional Reference Frame sub-commission for Europe, EUREF.	Croatian Geololgical Survey	Italian National Institute of Geophysics and Volcanology (INGV)	Department of Geophysics, Faculty of Science and Mathematics, University of Zagreb	Istituto Nazionale di Geofisica e Vulcanologia, Milan	Department of Geophysics, Faculty of Science and Mathematics, University of Zagreb	COMET, School of Earth and Environment, University of Leeds, England
Source locator	http://www.epncb.oma.be	http://www.hgi-cgs.hr/geoportal.htm	http://diss.rm.ingv.it/share-edsf	https://www.pmf.unizg.hr/geof/	https://emidius.eu/SHEEC	http://seizkarta.gfz.hr	https://comet.nerc.ac.uk/COMET-LiCS-portal
Source type	spatial dataset	spatial dataset	spatial dataset	spatial dataset	spatial dataset	spatial dataset	service
Distribution format	SINEX	PDF, 1:300 000 also as web application	MapInfo mif/mid ESRI shapefile	textual	MS Excel, Interactive web application	PDF, Interactive application	Raster (geotiff)
Reference coordinate system	Geocentric coordinate system for Europe	Projected coordinate system for Croatia HTRS96 / TM	Geodetic coordinate system for World	Geodetic coordinate system for World	Geodetic coordinate system for World	No standard map projection, orthogonal coordinates	Geodetic coordinate system for World
Temporal coverage	Start date: 1995	1982– (1:50 000), 1962–1992 (1:100 000), 2006–2009 (1:300 000)	n/a	Covers the period since 373 BC until today	Time window 1000–1899	Published in 2011	02.09.2016–31.05.2018
Spatial resolution	Station distances between 100 and 500 km or more.	Map scale: 1:50 000, 1:100 000, 1:300 000	n/a	n/a	n/a	Map is compiled at the approximate scale of 1:800 000	260 km x 360 km (per product)
Temporal resolution	Daily Hourly	Does not require frequent updating.	n/a	Regularly updated.	n/a	Planned revision and update every 5–7 years.	12 days
Restrictions and terms of use	Freely available.	Purchase or inquiry upon request.	Designed as "work in progress", and as such it is open to later additions and improvements	Croatian Earthquake Catalogue (CEC) is not available on line. It is stored in the archives of the Department of Geophysics of the Faculty of Science, University of Zagreb.	Open-access upon registration. It can be used for scientific purposes, only, quoting the reference indicated.	Freely available for download as PDF in full resolution. The maps were accepted as a part of the Croatian National Annex to the EC8 in 2012.	Open-access

Table 1. Overview of the availability, scale, precision and usage of the possible sources of geoinformation that could be used to address the current knowledge on ongoing geodynamic processes in the Republic of Croatia

.

2.2 Geology

Geological investigations are often based on collected data by field observations, i.e. geological mapping of surface strata and construction of geological cross-sections perpendicular and/or parallel to local and regional-scale faults and associated structures in the study area.

Beside structural data collected by field observations, geological mapping and construction of geological cross-sections incorporates data officially published on geological maps and other publications of the Croatian Geological Survey (e.g. available sheets of basic geological maps of the Republic of Croatia at the scale of 1:300 000, 1: 100 000 and 1: 50 000 (see Table 1), as well as thematic geological maps, e.g., geomorphological map, geochemical map, hydrogeological map, geological engineering map, etc.). Additional datasets used to tackle geodynamic processes may be collected data by geophysical campaigns conducted by INA d.d. Croatian oil company (e.g., 2D seismic profiles, recorded seismic 3D cubes, gravimetric and magnetometric data and borehole data). Available geological data are usually limited by map scale and constrained by temporal and spatial resolution.

Within the scope of the geological field investigations that can be used in investigation of geodynamic processes collected data usually resemble age, structural and textural properties of mapped stratigraphic units. Identification of geological boundaries and contacts, recording and measuring of the microtectonic data on fault and shear planes are used to compute paleostress field of the study area. Based on computed paleostress field for the certain area, geological investigations include correlation analysis between computed paleostress field and recent stress field. This implies that analysis of focal mechanism solution and collected geological data provide foundations that are used in precise reconstruction of the tectonic evolution of the certain area (Tomljenović et al., 2008; Herak et al., 2009; Matoš, 2014; Palenik et al., 2019).

Currently, there is no publicly and online available Croatian database of the seismogenic sources. However, such data bases exist in neighbouring countries. The most prominent examples are the European Database of Seismogenic Faults (EDSF) (URL9) and Database of Individual Seismogenic Sources (DISS) (URL10).

Database of Seismogenic Faults (EDSF) includes only faults that are identified and mapped as neotectonics active faults, i.e. possible seismogenic sources capable of generating earthquakes of magnitude equal to or larger than 5.5 (see Table 1). It aims to ensure a homogeneous input for use in ground-shaking hazard assessment in the Euro-Mediterranean area. The database of seismogenic faults and website are hosted and maintained by The Italian National Institute of Geophysics and Volcanology (INGV).

Database of Individual Seismogenic Sources (DISS) is a georeferenced repository of tectonic, fault, and paleoseismological information expressly devoted, but not limited, to potential applications in the assessment of seismic hazard at Italian and regional scale. All database records are fully parameterized, covering Italy and its surrounding seas and territories, the central Mediterranean (covering the area of the littoral Croatia), and sections of the Aegean Sea.

2.3 Seismology

Seismology provides the main research tools for investigating Earth's structure from surface to the core. Using the data about seismic wave travel times and fault mechanism it provides information about properties of the medium thus enabling inferences about structural and material composition of the Earth. By providing information on earthquake timing and location along with the information on elastic properties of the medium, seismology in combination with the geologic and geodetic data is indispensable in creating broad image about tectonic and surface geodynamics processes.

Earthquake data such as seismic wave travel times, earthquake locations, macroseismic reports, earthquake mechanisms, etc. are routinely collected and archived by the Department of Geophysics, Faculty of Science, University of Zagreb. Seismic hazard map of Croatia is also available (see Table 1), accepted as a part of the National Annex of the Eurocode-8. Earthquake hazard is presented by the values of peak ground acceleration (PGA) expected to be exceeded on the average every 95 and 475 years. Underlying statistical analyses was based on the Croatian Earthquake Catalogue, which was expanded with the data for events well outside Croatian borders.

Currently, there are over 25 permanent broadband seismic stations in Croatia continuously monitoring seismic activity in Croatia and neighbouring regions. Collected seismograms are regularly analysed and all the information about earthquakes are stored in the Croatian Earthquake Catalogue (see Table 1). The number and density of the seismic stations in the region ensures that the precision of earthquake locations will be in the 5 km range and the threshold magnitude about M = 1.0.

The Croatian Earthquake Catalogue (CEC) is the main database about the past and present earthquakes in Croatia covering period from 373 BC until today (Herak et al., 1996). The catalogue is routinely updated through combination of data about present earthquakes obtained with a semi-automatic location procedure and historical earthquake data collected thorough ongoing research. In the catalogue there is currently information on over 90,000 events with foci in Croatia and neighbouring regions.

Seismological data on earthquakes in the wider spatial frame (earthquake focal mechanisms, estimated maximal earthquake magnitude with regard to geometric parameters, focal depth, etc.) are publicly available in the form of the WebGIS database. Examples include the ISC-GEM Global Instrumental Earthquake Catalogue (1904–2015) (URL11) and the SHARE European Earthquake Catalogue (SHEEC) (URL12).

3. CONCLUSION AND FUTURE WORK

In this paper, the first step in the systematization of spatial data has been made to establish geodetic-geodynamic basis for future research of crustal deformations that are associated with plate motion and active faults on the territory of the Republic of Croatia.

We identified publically available sources of the diverse sets of site-specific geodetic, geological and seismological geospatial data which show that problems exist related to availability, organization, and sharing of these data. In Table 1 we listed the subjects that provide data, but only a small number of them have developed network services that provide data storage,

https://doi.org/10.5194/isprs-archives-XLII-3-W8-233-2019 | © Authors 2019. CC BY 4.0 License.

manipulation or presentation. Specifically, geological and seismological data (such as official Geological Maps of the Republic of Croatia and Croatian Earthquake Catalogue) are only available upon request, whereas geodetic GNSS and InSAR products (Croatia based) can be found only in scientific publications. Thus, we point out the necessity for an online database with visualization and sharing services of the existing and future geodetic data for geodynamic research in the Republic of Croatia. The good practice can be found in external data sources and ongoing projects such as NASA ARIA project for Natural Hazards (URL13). Moreover, geological databases should be focused on improving a usability of the existing data within GIS environment as well as development of database of seismogenic sources similar as the INGV European Database of Seismogenic Faults (URL9).

The future research should strive to identify other sources of geoinformation beside the ones mentioned in this study, which could be effectively used not only for the management and display but also for analysis and interpretation in the research context. Furthermore, considering the spatial component of geodynamic processes, the future research should be expanded to identify available geoinformation in a wider regional frame. Also, a comparison with existing well-established sources in the neighbouring countries could provide a better insight into solutions for integrated use of these data.

ACKNOWLEDGEMENTS

This work has been fully supported by the Croatian Science Foundation under the project number IP-01-2018-8944.

REFERENCES

Akarsu, V., Sanli, D.U., Arslan, E., 2015. Accuracy of velocities from repeated GPS measurements, *Nat. Hazards Earth Syst. Sci.,* 15, 875–884, https://doi.org/10.5194/nhess-15-875-2015, 2015.

Arnadottir, T., Jonsson, S., Pollitz, F.F, Jiang, W., Feigl, K.L., 2005. Postseismic deformation following the June 2000 earthquake sequence in the south Iceland seismic zone. *Journal of Geophysical Research*, Vol 110, doi.org/10.1029/2005JB003701.

Atzori, S., Hunstad, I., Chini, M., Salvi, S., Tolomei, C.B., Stramondo, S., Trasatti, E., Antonioli, A., Boschi, E., 2009. Finite fault inversion of DinSAR coseismic diplacement of the 2009 L'Aquila earthquake (central Italy). *Geophysical Research Letters*, Vol. 36. L15305, doi: 10.1029/2009GL039293.

Bekaert, D.P.S., Hooper, A., Wright, T.J., 2015. Reassessing the 2006 Guerrero slow-slip event, Mexico: Implications for large earthquakes in the Guerrero Gap. *Journal of Geophysical Research Solid Earth*, Vol 120, pp 1357-1375, doi.org/10.1002/2014JB011557.

Berardino, P., Fornaro, G., Lanari, R., Sansosti, E., 2002: A new algorthm for surface deformation monitoring based on small baseline differential SAR interferograms. *IEEE Transactions on Geoscience and Remote Sensing*, Vol 40, NO. 11, pp 2375-2383.

Bennett, R.A., Hreinsdottir, S., Buble, G., Bašić, T., Bačić, Ž., Marjanović, M., Casale, G., Gendaszek, A., Coan, D., 2008: Eocene to present subduction of southern Adria mantle lithosphere beneath the Dinarides. Geology, 36(1), pp. 3–6.

Burgmann, R., Thatcher, W., 2013. Space geodesy: A revolution in crustal deformation measurements of tectonic processes. *Special Paper of the Geological Society of America*. 500. 397-430. doi.org/10.1130/2013.2500(12).

Blewitt, G., Lavallee, D. (2002): Effect of annual signal on geodetic velocity. Journal of Geophysical Research: Solid Earth, Vol 107, doi: 10.1029/2001JB000570

Cakir, Z., Ergintav, S., Akoglu, A. M., Cakmak, R., Tatar, O., and Meghraoui, M., 2014. InSAR velocit field across the North Anatolian Fault (eastern Turkey): Implications for the loading and release of interseismic strain accumulation. *Journal of Geophysical Research Solid Earth*, Vol 119, pp 7934-7943, doi.org/10.1002/2014JB011360.

Cambell, J., Northnagel, A., 2000. Eurpean VLBI for crustal dynamics. *Journal of Geodynamics*, 30 (3), pp. 32-326.

Chaussard, E., Johnson, C.W., Fattahi, H., Burgman, R., 2016. Potential and limits of InSAR to charaterize interseismic deformation independently of GPS data: Application to the southern San Andreas Fault system. *Geochemistry, Geophysics, Geosystems,* Vol 17, pp 1214-1229, doi.org/10.1002/2015GC006246.

D'Agostino, N., Avallone, A., Cheloni, D., D'Anastasio, E., Mantenuto, S., Selvaggi, G., 2008. Active tectonics of the Adriatic region from GPS and earthquake slip vectors. *Journal of Geophysical Research*, Vol. 113, B12413, doi.org/10.1029/2008JB005860.

Dermanis A., Kotsakis C., 2006. Estimating Crustal Deformation Parameters from Geodetic Data: Review of Existing Methodologies, Open Problems and New Challenges. In: Sansò F., Gil A.J. (eds) Geodetic Deformation Monitoring: From Geophysical to Engineering Roles. *International Association of Geodesy Symposia*, vol 131. Springer, Berlin, Heidelberg. doi.org/10.1007/978-3-540-38596-7_2.

ElGharbawi, T., Tamura, M., 2015. Coseismic and postseismic deformation estiamtion of the 2011 Tohoku earthquake in Kanto Region, Japan, using InSAR time series analysis and GPS. *Remote Sensing of Environment*, Vol 168, pp 374-387.

Fattahi, H., Amelung, F., 2014. InSAR uncertainty due to orbital errors. *Geophysical Journal International*, Vol 199, pp 549-560, doi.org/10.1093/gji/ggu276.

Feng, M., Bie, L., Rietbrock, A., 2018. Probing the rheology of continental faults: decade of post-seismic InSAR time-series following the 1997 Manyi (Tibet) earthquake. *Geophysical Journal International*. Vol 215, pp 600-613, doi.org/10.1093/gji/ggy300.

Grenerczy, G., Sella, G., Stein, S., Kenyeres, A., 2005. Tectonic implications of the GPS velocity field in the northern Adriatic region. *Geophys. Res. Lett*. 32, L16311, doi.org/10.1029/2005GL022947.

Govorčin, M., Matoš, B. Herak, M. Pribičević, B., Vlahović, I., 2018: Coseismic deformation analysis of the 1996 Ston-Slano (southern Croatia) ML 6.0 earthquake: preliminary results using

DinSAR and geological investigations. *9th International INQUA Meeting on Paleoseismology, Active Tectonics and Archeoseismology*, 25-27 June 2018, Possidi, Greece.
Hanssen, R.F., 2001. Radar interferometry: data interpretation and error analysis. *Springer Science & Buisness Media*, Vol. 2.

Herak, M., D. Herak, Markušić, S., 1996. Revision of the earthquake catalog and seismicity of Croatia, 1908–1992, *Terra Nova,* **8**, 86–94.

Herak, D., Herak M., Tomljenović, B., 2009: Seismicity and earthquake focal mechanisms in North-Western Croatia, *Tectonophysics* 465, 212–220.

Hussain, E., Wright, T.J., Walters, R. J. Bekaert, D.P.S., Lloyd, R., Hooper, A., 2018. Constant strain accumulation rate between major earthquakes on the North Anatolian Fault. *Nature Communications*, Vol 9. doi.org/10.1038/s41467-018-03739-2.

Jonsson, S., Zebker, H., Segall, P., Amelung, F., 2002. Fault Slip Distribution of the 1999 Mw 7.1 Hector Mine, California, Earthquake, Estimated from Satellite Radar and GPS Measurements. *Bulletin of the Seismological Society of America*, Vol. 92, No. 4, pp. 1377-1389.

Jordan, T.G., Minster, J.B., 1988. Beyond plate tectonics – Looking at plate deformation with space geodesy. The impact of VLBI on astrophysics and geophysics; *Proceedings of the 129th IAU Symposium*, Cambridge, MA, May 10-15, 1987 (A89-13726 03-90). Dordrecht, Kluwer Academic Publishers, pp. 341-350.

Kaneko, Y., Hamling, I.J., Van Dissen, R.J., Motagh and Samsonov, S.V., 2015. InSAR imaging of displacement on flexural-slip faults triggered by the 2013 Mw 6.6 Lake Grassmere earthquake, central New Zealand. *Geophysical Research Letters*, 42, pp 781-788, doi:10.1003/2014GL062767.

Kreemer, C., Blewitt, G., Klein, E.C., 2014. A geodetic plate motion and global strain rate model // Geochemistry, Geophysics, Geosystems, 15 (10), pp 3849-3889.

Marinković, P., Ketelaar, G., van Leijen, F., Hanssen, R., 2008. InSAR quality control, analysis of five years of corner reflector time series. *Proc. Of FRINGE 2007 Workshop*, Frascati, Italy, 26 – 30 November 2007, ESA-SP-649.

Matoš, B., 2014. Neotectonic and recently active faults in Bilogora mountain area and assessment of their seismogenic potential 2014., Doctoral thesis, Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb.

Marjanović, M., 2008. Application of GPS measurements for determining horizontal and vertical movements of the Adriatic microplate. Doctoral thesis. Faculty of Geodesy, University of Zagreb.

Massonnet, D., Rossi, M., Carmona, C., Adragna, F., Peltzer, G., Feigl, K., Rabaute, T., 1993. The displacement field of the Landers earthquake mapped by radar interferometry. *Nature*, 364, pp 138-142, doi: 10.1038/364138a0.

Massonnet, D., Feigl, K.L., 1998. Radar interferometry and its application to changes in the Earth's surface. *Reviews of geophysics*, 36 (4), pp 441-500.

Medak, D., Pribičević, B., Đapo, A., 2002. Međunarodni projekti za priključivanje Hrvatske Europskoj geodetskoj zajednici (1992-2001). In T. Bašić (Ed.), *Zbornik Geodetskog fakulteta Sveučilišta u Zagrebu povodom 40. obljetnice samostalnog djelovanja 1962.-2002.*, pp. 71–80.

Motagh, M., Wang, R., Walter, T. R., Burgmann, R., Fileding E., Anderssohn, J. and Zschau, J., 2008. Coseismic slip model of the 2007 August Pisco earthquake (Peru) as constrained by Wide Swath radar observations. *Geophysical Journal International*, Vol 174, pp 842-848, doi.org/10.1111/j.1365-264X.2008.03852.x.

Murray-Moraleda, J., 2009. GPS: Applications in Crustal Deformation Monitoring. In: *Meyers R. (eds) Encyclopedia of Complexity and Systems Science. Springer, New York, NY*, doi.org/10.1007/978-0-387-30440-3_250.

Nissen, E., Elliot, J.R., Sloan, R.A., Craig, T.J., Funning, G.J., Hutko, A., Parsons, B.E., Wright, T., 2016. Limitations of rupture forecasting exposed by instantaneously triggered earthquake doublet. *Nature Geoscience*. Vol 9, doi.org/10.1038/NGEO2653.

Palenik, D., Matičec, D., Fuček, L., Matoš, B., Herak, M. and Vlahović, I., 2019. Geological and structural setting of the Vinodol valley (NW ADRIATIC, CROATIA): insights into tectonic evolution based on structural investigations. *Geologia Croatica; Journal Of The Croatian Geological Survey And The Croatian Geological Society (1330-030X) - accepted for publication.*

Osmanoğlu, B., Sunar, F., Wdowinski, S., Cabral-Cano, E., 2016: Time series analysis of InSAR data: Methods and trends. *ISPRS Journal of Photogrammetry and Remote Sensing*, 115, 90–102.

Pavasović, M., 2014. CROPOS as Croatian Terrestrial Reference Frame and its Application in Geodynamic Researches. Doctoral thesis, Zagreb, Faculty of Geodesy, University of Zagreb.

Pavasović, M., Bašić, T., Marjanović, M., 2015. An overview of scientific and professional projects in the field of basic geodetic works at the territory of Republic of Croatia in period from 1991-2009. *Geodetski vestnik*. 59 (2015), 4; 767-788.

Pedersen, R., Sigmundsson, F., Feigl, K.L., Arnadottir, T., 2001. Coseismic interferograms of two Ms=6.6 earthquakes in the South Iceland Seismic Zone, June 2000. *Geophysical Research Letters*, Vol 28, No. 17, pp 3341-3344.

Pribičević, B., Đapo, A., 2016. Movement Analysis on Geodynamic Network of the City of Zagreb from Different Time Epochs // Geodetski list, (0016-710X) 70(93), 3, pp. 207-230.

Pribičević, P., Đapo, A., Govorčin, M., 2017. The application of satellite technology in the study of geodynamic movements in the wider Zagreb. *Tehnički vjesnik*, Vol 24, No.2 pp 503-512, doi.org/10.17559/TV-20160817013320.

Schmid, S.M., Bernoulli, D., Fugenschuh, B., Matenco, L., Schuster, R., Schefer, S., Tischler, M., Ustaszewski, K., 2008. The Alpine-Carpathian-Dinaridic orogenic system: Correlation and evolution of tectonic units. *Swiss J. Geosci*., 101, pp. 139–183.

Tari, V., 2002. Evolution of the Northern and Western Dinarides: a Tectonostratigraphic Approach. In: *Stephan Mueller Special Publication Series*, vol. 1, pp. 223–236.

Tomljenović, B., Csontos, L., Márton, E., Márton, P., 2008. Tectonic evolution of the northwestern Internal Dinarides as constrained by structures and rotation of Medvednica Mountains, North Croatia, *Geological Society, London, Special Publications* 2008; v. 298; p. 145-167, doi.org/10.1144/SP298.8

Weber, J., Vrabec, M., Pavlocčič-Prešeren, P., Dixon, T., Jiang, Y., Stopar, B., 2010. GPS-derived motion of the Adriatic microplate from Istria Peninsula and Po Plain sites, and geodynamic implications, *Tectonophsics*, 483, pp. 214-222.

Wang, K. and Fialko, Y., 2018. Observations and Modeling of Coseismic and Postseismic Deformation Due to the 2015 Mw 7.8 Gorkha (Nepal) Earthquake. *Journal of Geophysical Research Solid Earth*, Vol 123, pp 761-779, doi.org/10.1002/2017JB014620.

Wright, T. J., Lu, Z., Wicks, C., 2003. Source model for the Mw 6.7, 23 October 2002, Nenana Moutain Earthquake (Alaska) from InSAR. *Geophysical Research Letters*, Vol 30 NO. 18, doi.org/10.1029/2003GL018014.

URL1: CROatian Positioning System (CROPOS), https://www.cropos.hr, Accessed 18 June 2019.

URL2: Rete Integrata Nazionale GPS (RING), http://ring.gm.ingv.it, Accessed 18 June 2019.

URL3: SlovenIja-Geodezija-NAvigacija-Lokacija (SIGNAL), http://www.gu-signal.si, Accessed 18 June 2019.

URL4: Hungarian active GNSS network (GNSSnet.hu) https://www.gnssnet.hu, Accessed 18 June 2019.

URL5: Network of permanent GNSS stations of the Federation of Bosnia and Hercegovina (FBiHPOS), http://www.fgu.com.ba, Accessed 19 June 2019.

URL6: Network of permanent GNSS stations of the Republic of Srpska (SRPOS), https://www.rgurs.org/lat/servisi/srpos, Accessed 18 June 2019.

URL7: GNSS permanent station networks to satisfy accuracy (MontePOS), http://www.nekretnine.co.me/me/Montepos.asp, Accessed 18 June 2019.

URL8: COMET-LiCS Sentinel-1 InSAR portal, https://comet.nerc.ac.uk/COMET-LiCS-portal, Accessed 18 June 2019.

URL9: European Database of Seismogenic Faults (EDSF), http://diss.rm.ingv.it/share-edsf, Accessed 18 June 2019.

URL10: Database of Individual Seismogenic Sources (DISS), http://diss.rm.ingv.it/diss, Accessed 18 June 2019.

URL11: ISC-GEM Global Instrumental Earthquake Catalogue, http://www.isc.ac.uk/iscgem, Accessed 18 June 2019.

URL12: SHARE European Earthquake Catalogue (SHEEC), https://www.emidius.eu/SHEEC, Accessed 18 June 2019.

URL13: Advanced Rapid Imaging and Analysis (ARIA), https://aria.jpl.nasa.gov, Accessed 18 June 2019

The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-3/W8, 2019
Gi4DM 2019 – GeoInformation for Disaster Management, 3–6 September 2019, Prague, Czech Republic

COMPARATIVE ANALYSIS OF TAXONOMY, STANDARDISATION AND AVAILABILITY OF CARTOGRAPHIC SYMBOL SETS FOR CRISIS MAPPING

A. Kuveždić Divjak [1]*, B. Pribičević [1], A. Đapo [1]

[1] Faculty of Geodesy, University of Zagreb, Zagreb, Croatia - (akuvezdic, bpribic, adapo)@geof.hr

Commission VI, WG VI/4

KEY WORDS: Cartographic Symbols, Crisis Maps, Comparative Analysis, Taxonomy, Promulgation, Sharing, Standardisation

ABSTRACT:

Cartographic symbols on crisis maps serve as the means of depicting information about the position, properties, and/or numerical values of objects, phenomena or actions specific to crisis mapping. The aim of symbology for many crisis cartographic visualisations are simple, clear, aesthetically pleasing symbols that can be easily used and understood by a wide range of crisis map users. If they are incomprehensible, illegible, ambiguous, unclassified, and random, if they lack hierarchical organisation and other characteristics which are important when designing a cartographic symbol set, they can fail to deliver the intended message. In addition to effective graphic design, cartographic symbol sets for crisis mapping are facing additional challenges, including consideration of their availability (sharing and promotion, dissemination and promulgation) and standardisation (ensuring the general and repeatable use of map symbols). To determine the extent of these challenges and to assess the current state of the cartographic symbology for crisis mapping we have compiled and compared the prominent examples of symbol sets that were promoted in the cartographic scientific and crisis mapping community in recent years. We pay particular attention to those sets that have gone through a new, reviewed or extended edition. We research whether the latest changes incorporated follow the recognised challenges posed to the crisis mapping symbology.

1. INTRODUCTION

A crisis map is a thematic map on which objects, phenomena or actions specific to crisis management are represented according to their importance and highlighted using appropriate cartographic symbols. Cartographic symbols on crisis maps serve as the means of depicting information about the position, properties, and/or numerical values of objects, phenomena or actions specific to crisis mapping. The problem of ineffective mapping that has failed in communicating messages during a crisis has been identified following Hurricane Andrew (in the Bahamas and the southeastern coast of the USA in 1992) and Hurricane Fran (in the USA in 1996) (Dymon, 2003), when retrograde research was conducted on how the maps produced during or immediately after these events were used. This was confirmed once again after major tragedies, such as the “9/11” terrorist attack (in the USA in 2001), the “Christmas” tsunami (on the coasts of Indonesia, Thailand, Sri Lanka, and India in 2004) and Hurricane Katrina (in the USA, 2005). Immediately after these events, problems were identified, such as the lack of cartographic symbols for communication in crisis situations, and visually overloaded maps which reduced legibility and made orientation and understanding essential crisis information difficult (Akella, 2009).

The need to conduct research on cartographic symbols that are specifically adapted for usage on crisis maps was highlighted. It resulted in publicly available cartographic symbol sets that were promoted in recent years within the crisis community. Examples include: *Emergency Response Symbology* (Homeland Security Working Group, Federal Geographic Data Committee, USA, 2005) (ANSI, 2006); *Canadian All-Hazards Symbology For Emergency Management* (Government Operations Center, Canada, 2015) with its predecessors: *Canadian Disaster Database Symbology* (2007) and *Emergency Mapping Symbology* (GOC, 2015); *Australian All Hazards Symbology* (Emergency Management Spatial Information Australia, Australia, 2007) with a revised edition issued in 2018 (EMSINA, 2018); *OCHA's Humanitarian Icons* (United Nations Office for the Coordination of Humanitarian Affairs (OCHA), International, 2012) with a completely revamped set of symbols released in 2018 (UN OCHA, 2018); *MIL-STD-2525D Common Warfighting Symbology, Appendix G* (Department of Defense, USA, 2008) (DOD, 2014); *Humanitarian Demining Symbols* (Geneva International Center for Humanitarian Demining, International, 2005) (GICHD, 2005); *Symbol System for Disaster Management* (Laboratory on Cartography, Sofia University of Architecture, Civil Engineering and Geodesy, 2017, Bulgaria) (Marinova, 2018); *European Emergency Symbology reference for 2D/3D maps* (INDIGO project, Europe, 2012) (INDIGO, 2012); *Civil Protection Common Map Symbology* (Ordnance Survey, UK, 2012) (Cabinet Office, 2012).

In a recent study (Kostelnick, Hoeniges, 2018) four general challenges related to the development of crisis map symbology were identified through a review of the cartographic literature as well as from survey across the community of humanitarian relief organisations. The challenges include consideration of the following: symbol taxonomies, design issues, standardisation, sharing and promulgation. To determine the extent of these challenges in the current state of the crisis mapping symbology we have compiled and compared the prominent examples of symbol sets that were promoted in the cartographic scientific and crisis mapping community in recent years. We paid particular attention to those sets that have gone through a new,

* Corresponding author

https://doi.org/10.5194/isprs-archives-XLII-3-W8-241-2019

reviewed or extended edition and researched whether the latest changes follow the challenges posed to the crisis mapping symbology.

We are guided by the following research questions: (1) What crisis symbology sets exist currently publicly available for use? (2) What do the taxonomy of cartographic symbols in sets and their internal breakdown look like? What graphical variables have been used to support visual and cognitive organisation of the symbols within the set? (3) Is it possible to expand the set with additional symbols? Have the guidelines for the graphic design of new symbols been given? Has an assessment of the design, efficiency, and recognition of cartographic symbols on crisis maps been carried out? (4) How do we know the symbol set exists? How and in which format have the symbols been shared? Have they been promoted? Are there, in addition to the symbols, materials available for learning and training (such as examples of the use of map symbols, manuals for their use, "best practices" guidelines)? (5) Is the set updated? Has it been re-edited? If so, what changes have been implemented?

In this research, our intent is to gain an insight into the existing practices that we encounter in the context of three categories that have been identified by (Kostelnick, Hoeniges, 2018): taxonomy of symbols; standardisation of crisis map symbols; sharing and promulgation of crisis map symbols, i.e. their availability. Challenges placed in the fourth category, i.e. the process of designing the visual appearance of crisis symbols, will be the subject of separate analysis in future research.

2. COMPARATIVE ANALYSIS OF CARTOGRAPHIC SYMBOL SETS FOR CRISIS MAPPING

2.1 Materials and Methods

We collected six existing, publicly available cartographic symbol sets that were published in different countries. Three sets are designed exclusively for crisis management (*Emergency Response Symbology, Canadian All-Hazard Symbology, Australian All Hazard Symbology*), while two are intended for humanitarian activities (*OCHA's Humanitarian Icons and Humanitarian Demining Map Symbols*), and one for military operations (*MIL-STD-2525D Common Warfighting Symbology*). Regardless of their primary purpose, all listed cartographic symbol sets are publicly available online, they contain symbols for representing objects, phenomena, and actions specific to crisis management and were recognised and promoted in the cartographic scientific and crisis mapping community (Bianchetti et al., 2012, Robinson et al. 2010, Koselnick et al., 2008; Marinova, 2018), which were the main criteria for their selection.

If the symbols in the set are classified into groups, we analysed their *taxonomy* – the division that categorises the objects, phenomena, and action for display on crisis maps and organised them into groups based on their similarity and difference. We analysed how the thematic organisation into categories was transferred into the graphical appearance of the symbols, i.e. which graphic variables (e.g. colour, shape, size, etc.) were used. Transcription in the cartographic symbol set must, on the one hand, be selective to clearly distinguish the affiliation to a particular type, and also, within each type, it must be associative to clearly show its affiliation (MacEachren, 1995).

In terms of *standardisation*, we analysed which measures were taken regarding the general and repeated use of cartographic symbols from the set. We explored if the possibility of extending the set with additional symbols was provided, and whether there are guidelines, requirements, and rules for graphical design and the rules for implementing these symbols on crisis maps. We researched if an assessment of the design, efficiency, and recognition of cartographic symbols on crisis maps was carried out? Is there any recorded usage of symbols on maps in real-case scenarios? We analysed whether the symbols are intended for use on a certain type of map at a certain scale.

Regarding *availability* we analysed the methods of sharing and promoting, dissemination and promulgation of the cartographic symbol sets. Methods for the dissemination of symbols from existing sets, such as promotions, publications, presentations, workshops, brochures, flyers, posters, websites, exhibitions, conferences, training activities, innovation networks, and more were identified. We made an overview of the technical aspects of how the cartographic symbols were shared, such as the format available for download, if embedded in existing GIS software (ArcGIS and QGIS) or symbol sharing platforms. We also researched and listed which accompanying materials are available, such as learning and training materials, demonstrative examples of the use of symbols on maps, manuals for their use, guidelines for "best practices", and the like.

We synthetized the results of a comparative analysis and present our findings to each of the issues in following subchapters.

2.2 Taxonomy, visual and hierarchical organisation of cartographic symbols in existing sets

By analysing the existing sets, different approaches to the hierarchical, thematic and visual organisation of cartographic symbols within an individual set have been observed. For example, symbols from the *Canadian All-Hazards Symbology* are organised into three categories, while *Emergency Response Symbology, Australasian All Hazard Symbology* and *MIL-STD-2525D Common Warfighting Symbology* are organised into four categories. Symbols in the *OCHA's Humanitarian Icons* set are organised into 16 categories and in the *Disaster Response Map Symbols* set there is no such division. Although the total number of categories and their names differ in the existing sets, general similarities can be found. *Incidents*, *operations* and *infrastructure* are pointed out as three commonly used categories for the thematic organisation of cartographic symbols for communication and action in a crisis. In *Emergency Response Symbology, Canadian All-Hazards Symbology* and *Australian All Hazard Symbology* sets, the visual organisation is achieved by connecting a different geometric shape to a particular category of symbols (Figure 1). In a new version of the *Australian All Hazard Symbology* from 2018 new category of observations has been added for features which are affected or impacted by the incident (Figure 1).

In the *Emergency Response Symbology* set a visual hierarchical status on the damage caused, marked by a particular geometric shape and/or colour of the symbol frame, can be additionally assigned to the symbols from the operations and infrastructure categories (Figure 2). In a new edition of the *Australian All Hazard Symbology set,* the novelties are graphic variables for expressing the ordered (hierarchical) properties. A visual hierarchical status for incidents (*Confirmed* and *Unconfirmed*) and for operations (*Established* and *Planned*) is marked with a full or dotted line. The status of the asset *Potentially Defendable*, *Defendable, Not Defendable* is marked with a

https://doi.org/10.5194/isprs-archives-XLII-3-W8-241-2019

circle, a checkmark, or a cross within the symbol frame (Figure 3). Usage of the scale of colours of the same brightness enables the additional selective emphasis of the features effected by the incident: *No Damage* (green), *Slight damage* (blue), *Moderate damage* (yellow), *Severe damage* (orange), *Total damage* (red) (Figure 4).

Following the example of the *Emergency Mapping Symbology*, a new version of the *Canadian All-Hazards Symbology* incorporated the use of different frames – diamond for an incident, rectangle for infrastructures, and circle for operations. Frame with dashes represents a disruption to an incident or infrastructure. When the symbology set is distributed, these frames will be provided for users to combine them with any symbol (GOC, 2015).

In the *MIL-STD-2525C Common Warfighting Symbology* set, framing the symbols with frames of different shapes, or fills in different colours, *affiliation* is marked – the relationship between an operator and an operative object. The basic categories of affiliation are: *unknown*, *friendly, neutral* and *hostile*. A symbol with a light yellow filling is used to denote an unknown affiliation, a rectangle with a light blue filling to denote a friendly affiliation, a square with light green filling for neutral affiliation, and a square with a red filling to denote a hostile affiliation.

Although the symbols in the sets *OCHA's Humanitarian Icons* and *Humanitarian Demining Map Symbols* are thematically organised into categories, this organisation has not been transferred into the graphic appearance of these symbols, as can be seen from the examples given in Figure 5. Since all the symbols in the *OCHA's Humanitarian Icons* set are of the same colour, the associative and selective properties were not achieved. Although pictograms in *Humanitarian Demining Map Symbols* set use frames of different geometric shapes and different colour fills, these variables were not applied to achieve the visual organisation of the symbols but arbitrarily.

2.3 Availability (sharing, dissemination, and promulgation) of the cartographic symbols from existing sets

2.3.1 Availability via web page and format

Emergency Response Symbology is publicly available on the web pages of the Homeland Security Working Group of the Federal Geographic Data Committee (URL1) from 2004. In addition to symbols, the necessary explanations of the meaning of each symbol are provided. Symbols are available for download in a form of a TrueType font, with the note that they are "a Government work, not subject to copyright protection, and may be published/disseminated without restriction(s)".

Canadian All-Hazards Symbology was publicly released by Government Operations Centre Geomatics (GOC) in 2015 in the document (GOC, 2015). It is currently available at (URL2), but the permanent host is required. The symbols are available for download in PNG and TrueType format and ESRI Style file. The license includes the right to use, incorporate, modify, improve, and further develop the symbols. The intellectual property rights arising from any modification, improvement, development or translation of the symbology or the manufacture of any other products, effected by or for the Licensee, shall vest in the Licensee or such person as the Licensee shall decide (GOC, 2015).

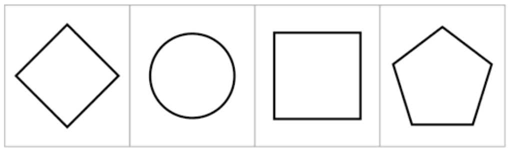


Figure 1. *Incidents* (diamond), *Operations* (circle) and *Infrastructure* (rectangle) are used for thematic and visual organisation of cartographic symbols in *Emergency Response Symbology, Canadian All-Hazards Symbology* and *Australian All Hazard Symbology*. Category *Observations* (pentagon) is added in new version of *the Australian All Hazard Symbology.*

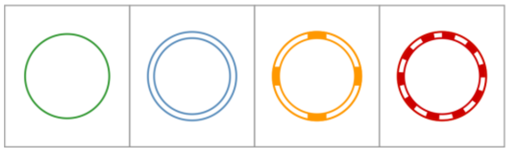


Figure 2. In *Emergency Response Symbology* a visual hierarchical status on the damage and operational level from *Fully operational* (left) to *Totally incapacitated* (right) can be additionally assigned to the symbols from the categories *Operations* and *Infrastructure.*

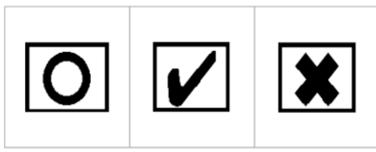


Figure 3. Ordered property for representing the status of the asset *Potentially Defendable* (circle), *Defendable* (checkmark) and *Not Defendable* (cross) within the symbol frame is available in new version of the *Australian All Hazard Symbology.*

Figure 4. A scale of colours of the same brightness for additional selective emphasis of the features effected by the incident is available in a new version of the *Australian All Hazard Symbology.*

Figure 5. Thematic organisation has not been transferred into the visual appearance of the symbols in *OCHA's Humanitarian Icons* (top) and *Humanitarian Demining Map Symbols* (bottom). The associative and selective properties of cartographic symbols were not achieved.

This contribution has been peer-reviewed.
https://doi.org/10.5194/isprs-archives-XLII-3-W8-241-2019 | © Authors 2019. CC BY 4.0 License.

Predecessors of the *Canadian All-Hazards Symbology* set are *Emergency Mapping Symbology* from 2010 and *Canadian Disaster Database* from 2007. The design style used for *Emergency Mapping Symbology* involved very bright colours, gradient fills and a colour scheme to indicate the category for each symbol. The intended purpose of this style was to facilitate legibility on different web maps. The *Canadian All-Hazards Symbology* design differs from the *Emergency Mapping Symbology* as it was created for a different purpose. The *Canadian All-Hazards Symbology* was prepared primarily for desktop mapping, while still enabling effective web use. It was designed to stand out well on vector-based maps, as well as maps with raster backgrounds, such as topography or satellite imagery (GOC, 2015).

Emergency Mapping Symbology is no longer available, the sources on which it was distributed have been turned off, and traces of its existence can be found today only in scientific cartographic resources (e.g. Bianchetti et al., 2012). The *Emergency Mapping Symbology* set involved a large taxonomy covering a total of 249 events, infrastructures and operations. After consultation with the Government of Canada operations centres, *Canadian All-Hazards Symbology* used that taxonomy and expanded it to accommodate additional requirements.

In 2007, Public Safety contracted the development of symbology for use on the *Canadian Disaster Database* interactive web map. The design style followed that of the US *Emergency Response Symbology*. The *Canadian Disaster Database* symbols were utilised by the Government of Canada's Government Operations Centre (GOC) Geomatics group in many of its mapping products over the years. Over time, an expanded set was required by GOC Geomatics to incorporate more events and increase consistency across their mapping products.

In 2018 the *Australian All Hazards Symbology* set had its second edition. The process, the symbol set, related documents and the entire project history can be found on the website of Emergency Management Spatial Information Australia (URL3). A range of new symbols have been submitted and considered by Emergency Management Spatial Information Australia (EMSINA) since the adoption of the set in 2010, and in September 2018 an updated set of *Australian All Hazards Symbology* was released. This included an addition to the symbology framework and 15 new emergency management symbols. Symbols are available for download at (URL3) in KML, PNG, ESRI Style, TrueType fonts, SVG, and XML formats, and are customised for use in Avenza, ESRI, GeoServer, Google, Map Info, which is a major breakthrough compared to the previous version of this set which was only publicly available as a PDF document. While the old version was licensed under *Creative Commons Attribution 3.0 Australia* which permitted free use, copying, distribution, and customisation, terms of use for the new version has not been found.

The *OCHA's Humanitarian Icons* set is publicly available on the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) web site since 2012 (UN OCHA, 2012). Symbols are available for download free of charge as a PDF document, individual PNG and SVG files or as AI and PPT files with referencing "Source: OCHA" whenever possible. In 2018 OCHA released a completely revamped set of 295 (and counting) symbols, the result of a long and meticulous redesign process.

The *MIL-STD-2525* norm is publicly available on the web site of various military institutions (e.g. URL4) since 2008 and can be viewed and downloaded as a PDF document. *MIL-STD-2525 Common Warfighting Symbology*, in addition to detailed definitions and descriptions of military operations, contains six sets of military symbols subdivided into appendixes. The appendix G contains symbols for the management of extraordinary situations and is the subject of this research. It consists of a general section which sets out the objectives, references, definitions, general and detailed requirements and conditions of this symbol collection for acting in emergency situations. The official document containing the cartographic symbol collection is released in PDF format (DOD, 2014).

On the web site of the Geneva International Center (URL5), since 2015 there has been a publicly available report (GICHD, 2005) with a corresponding set of *Humanitarian Demining Symbols* in which, in addition to the graphic appearance, there are necessary interpretations of the meaning of each symbol. Symbols are available for download as TrueType font or ESRI style file, under the *Creative Commons* licence that permits free use, copying, distribution and customisation of symbols.

2.3.2 Availability at Other Locations and Attempts of Sharing in other Formats

The comparative analysis showed that cartographic symbols are most commonly shared via the organisation's website in different proprietary formats. The most common formats are the raster PNG, and vector SVG format. Vector formats, such as SVG, allow symbols to be scalable and customisable and colours to be selected for foreground, background, and frames.

Technical resources also included predefined style files for ESRI's ArcGIS for all analysed symbol sets and for QGIS (in the case of *OCHA's Humanitarian Icons* and *Australian All Hazards Symbology*) that could be loaded into standard mapping software to promote easy sharing within and among organisations.

The *OCHA's Humanitarian Icons* set is the only representative of cartographic symbols for crisis and humanitarian mapping within the Noun Project (The Noun Project, 2014) – a platform that offers a crowdsourced collection of universally recognisable icons for visual communication.

Symbols from the *Emergency Response Symbology* set are built-in in *Symbol Store,* a visual-enabled, web-based interactive tool designed to help mapmakers share point symbols (Robinson et al., 2013). The initial idea behind *Symbol Store* was to allow users to browse symbols by keyword, category tags, and contributors and to facilitate discovery, retrieval and sharing of map symbol sets between users. Symbol sets can be downloaded as ESRI Style Files so that they can easily be imported into new or current ArcGIS map projects.

Joint Military Symbology XML (JointMilSyML or JMSML) is an XML schema, and associated instance data, designed to document the contents of MIL-STD 2525D and NATO STANAG APP-6(C). The Military Overlay is supplied as a project template for ArcGIS Pro and it allows creating military standard symbols quickly by using and adapting existing feature templates, creating a military overlay with military standard symbols and sharing the overlay as either a static image or a web map (DOD, 2014). It is hoped that future defence and intelligence systems will be engineered to take advantage of this

https://doi.org/10.5194/isprs-archives-XLII-3-W8-241-2019

technology and, in so doing, accelerate the delivery of new military symbology, reflected in updates to these standards, to warfighters.

2.4 Standardisation (General and Repeated Use) of Cartographic Symbols from Existing Sets

2.4.1 Standardisation of Map Symbology

To date, essentially only one set of truly standardised emergency symbology exists. That is *Emergency Response Symbology* used in the United States and standardised by the American National Standards Institute (ANSI, 2006).

After public release, cartographic symbols of the *Emergency Response Symbology* triggered the great interest of crisis management experts and emergency service workers. Various software producers wanted to include cartographic symbols into their software, which would increase their availability and consistent use on crisis management maps. However, since the symbols were adopted as a standard of *American National Standards Institute*, their use implies the payment of a fee, which has rejected many users who are still using their free version. Standardised set has been officially used among the emergency management and first responder communities at all levels of need in the United States (i.e., national, state, local and incident) (URL1).

MIL-STD-2525D Common Warfighting Symbology is a norm setting out rules and requirements for defining and displaying military operations, and all units of the US Department of Defense (DOD) have been obliged to apply it since 2008. It is also available for use by non-DOD entities (e.g., first responders, United Nations, and multinational partners).

The equivalent to this standard are two NATO publications: *Allied Procedural Publication APP-6A – Military Symbols for Land Based Systems* and *Allied Procedural Publication APP-6B – Joint Symbology* from 1998, in which graphical symbols for marking units, positions and control measures in tactical operations are defined. Content of NATO's publications and standards *MIL-STD-2525* of the Department of Defence is basically the same, but the MIL-STD-2525 standard has been developing faster, and therefore the analysis in this paper refers to that standard.

2.4.2 Standardisation of Usage

In the *Emergency Response Symbology* it is stated that they are intended for use on digital and paper maps, in large and medium scale. It is not recommended to use symbols on small scale maps, but if necessary, it is advisable to use its simplified version or geometric shape that indicates the symbol category (URL1). In the *Australian All Hazard Symbology* it is stated that the symbols are intended for use on paper and digital topographic maps and aerial images, in small, medium and large scale. More detailed standardisation of their use in the studied resources was not found. However, the novelty in version released in 2018 is the inclusion of five scale-dependent symbols for facilities (*Fire-Fighting Facility, Ambulance Facility, State Emergency Service Facility, Life-Saving Facility* and *Police Facility*) for their use in smaller scales. Also, for the new added category *Observations* in which, frame fills in different colours of the same intensity, selectively outline the information on the damage caused, alternative variants for the black and white variants of the symbols are also foreseen (EMSINA, 2019). In the *Canadian All-Hazards Symbology* it is stated that they are primarily intended for desktop mapping, while still enabling effective web use (GOC, 2015). Symbols from the *OCHA's Humanitarian Icons* set are intended for use on a wide range of information *OCHA's* humanitarian community products, which usually include maps, written reports, infographics and websites, while symbols from *MIL-STD-2525D Common Warfighting Symbology* are intended for use on paper military topographic maps, digital military information systems, "graphics" and "working maps" (DOD, 2014). Symbols from the *Humanitarian Demining Map Symbology* set are intended for use on topographic maps and aerial images in digital and paper form, in large, medium and small scale, and are specially adapted for use in the mine action information set (*Information Management System for Mine Action IMSMA*) distributed by the Geneva International Humanitarian Demining Centre (GICHD, 2005).

In addition to the ways of use stated here that are mostly general, more detailed guidelines and rules for proper application of cartographic symbols on crisis maps have not been found.

2.4.3 Extension of the Set with New Symbols

Homeland Security Working Group responsible for the development of *Emergency Response Symbology* points out that the set does not include all the symbols required to represent the object, phenomena, and crisis-specific action. If there is a need for new symbols, they will try to incorporate them into an existing set depending on the available resources and capabilities (URL1). However, guidelines for extending the existing set with new symbols are not publicly available.

The current version of the *Australian All Hazard Symbology* set does not include all the cartographic symbols needed to manage different crises. It is stated that the existing symbols are limited to action in certain types of crisis and provide a basis that will be extended in the future to meet the wider needs of national security and crisis management (URL3). The 2010 version contained a total of 83 symbols. Between 2011 and 2017 EMSINA remained active in collecting information about new and/or improved *Australian All Hazard Symbology*. A dedicated symbology officer was elected in 2015. This person in collaboration with a small EMSINA working group revised the method of collecting and approving symbols in 2016. The latest version of the 2018 set contains a total of 127 symbols. However, the guidelines for extending the existing set with new symbols do not exist or have not been published in the available resources. However, a workflow for new *Symbology* proposals (URL3) has been clearly stated.

The *OCHA's Humanitarian Icons* set is being periodically extended with new symbols as necessary (UN OCHA, 2018), and when other versions of the set were released, a major step forward was made in the effort to standardise the guidelines for extending the existing set with new symbols. In 2018 OCHA released a completely revamped set of 295 (and counting) symbols, the result of a long and meticulous redesign process. The first version from 2012 contained a total of 241 symbols. While the 2012 set grew organically as the illustrations were developed to meet internal design needs, the new series has been drawn from scratch following standardised design rules. The document *OCHA Graphics Stylebook* (UN OCHA, 2018) was released. The given guidelines are not intended to be restrictive or to limit creativity; they are simply to help establish

https://doi.org/10.5194/isprs-archives-XLII-3-W8-241-2019 | © Authors 2019. CC BY 4.0 License.

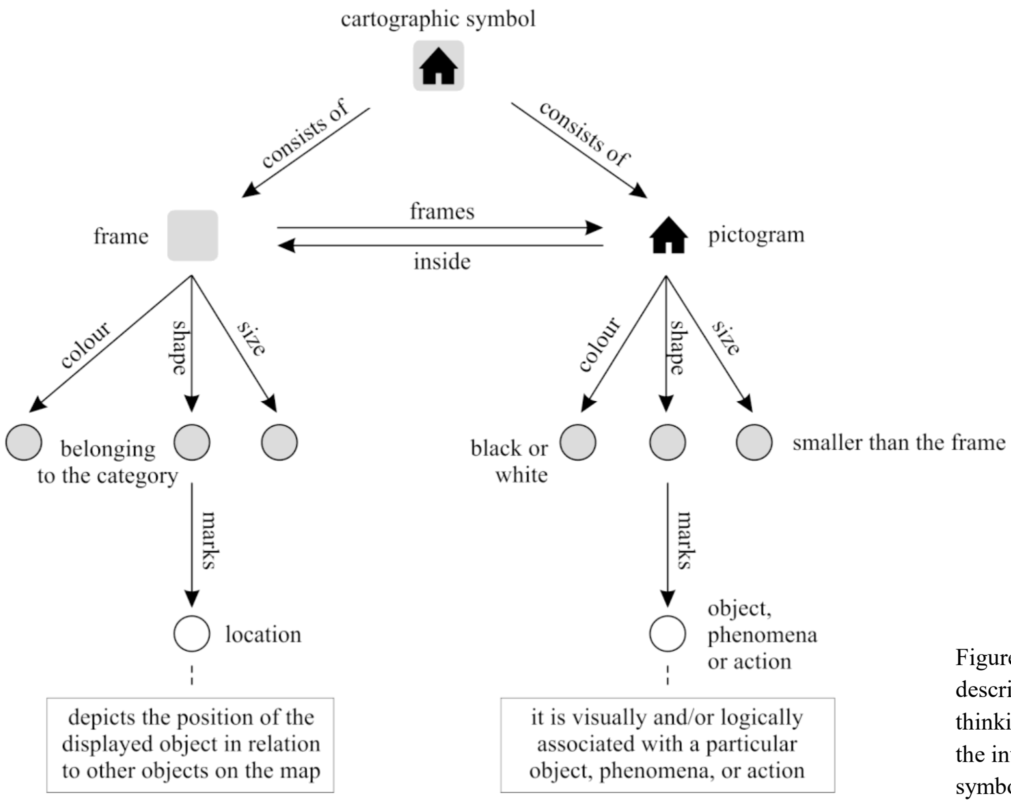


Figure 6. Cognitive scheme describing a recognised pattern of thinking and behaviour of users in the interpretation of cartographic symbols for crisis mapping

some rules for all designers so that there is consistency across the icon family. Because of this, all the new icons look similar in terms of visual complexity and appear to belong to the same "family". Moreover, the original set has been extended to include new themes (for instance cash transfer) and individual icons have evolved to reflect changes that occurred since 2012 (in technology, for example).

2.4.4 Assessment

Assessing the symbol design and recognisability from the *Emergency Response Symbology* set was conducted in two ways, and test methods and detailed results were published (URL1; Akella, 2009). In the first case, the assessment of the appearance of each symbol was conducted by the *Homeland Security Working Group* during December 2003 and January 2004, in an on-line open-type survey in which various crisis management and emergency services volunteers participated. Survey results were published in the report on the web site of the *Homeland Security Working Group* (URL1). For each symbol from the set, the participants of the survey needed to state if they *accept* or *reject* graphical design and short definition of a single symbol. Symbols that did not reach the 75% acceptance threshold have been reviewed and redesigned (e.g. in category *incidents* 11 symbols have not been accepted, in the category *natural events* 7, in the category *activity* 4, and in the category *infrastructure* no symbol was accepted). Those symbols that met the set threshold were accepted as a standard of *The American National Standardization Institute ANSI INCITS 415-2006 Homeland Security Mapping Standard - Point Symbology for Emergency Management.* In the same period (Akella, 2009) conducted test of recognition of 15 randomly selected symbols from the category *Incidents* and 13 symbols from the category *Operations*. Since there are no clear guidelines or norms to test the recognition of cartographic symbols for a crisis, (Akella, 2009) adopted the standard recommendations *ANSI Z535.3 National Standard for Criteria for Safety Symbols* which prescribes general criteria for the assessment and use of safety symbols indicating specific hazards. Fifty Californian fire-fighters participated in the testing and it was found that only 6 of the 28 rated symbols achieved an 85% recognition level, which is prescribed by the standard.

Assessment of the symbol design of the *Humanitarian Demining Map Symbols* was conducted when the symbols were in the initial version. Professional pyrotechnicians participated in the testing and their comments and feedback were taken into account in the transformation of the symbols in the newer versions of the system (Kostelnick et al., 2008).

For other symbol sets covered by the existing literature and other available resources, there is no evidence that the design, effectiveness, or recognisability of the proposed cartographic symbols was assessed.

3. DISCUSSION

In this paper, a comparative analysis of six existing, publicly available cartographic symbol sets that have been promoted since 2005 in the scientific cartographic community and the crisis management community was conducted. An overview of the taxonomy, visual and hierarchical organisation, availability (sharing, dissemination and promulgation) and standardisation (general and repeated use) of cartographic symbols gave an assessment of the current situation in the field of cartographic symbols for crisis mapping from which the following conclusions can be drawn.

For a proper understanding of the cartographic symbol set, i.e. to achieve the optimal map function for communicating information in a crisis, it is necessary to form the symbols by following the appropriate organisational structure. Although the

https://doi.org/10.5194/isprs-archives-XLII-3-W8-241-2019

data that is required to be displayed on the map has sometimes already been provided to the cartographer in a proper organisational structure, in the case of data for communication and acting in a crisis, such structure does not exist. However, the analysis of the existing sets has shown that some similarities can still be found in the way the organisation of cartographic symbols into groups was made in *Emergency Response Symbology, Canadian All-Hazards Symbology, Australian All Hazards Symbology* and *MIL-STD-2525D Common Warfighting Symbology*).

The visual organisation of the symbols in the set should be such that crisis management participants (who are at the same time both cartographers and map users) can spontaneously notice it (Bianchetti et al, 2012). This can be achieved by using the appropriate colours and different shapes for framing cartographic symbols as it has been made in sets *Emergency Response Symbology*, *Canadian All Hazard Symbology* and *MIL-STD-2525C Common Warfighting Symbology.*

Cartographic symbols for communicating in crisis should be designed to take advantage of the well-known tendencies of human perceptual organisation that lead to an approximately automated interpretation of certain relationships through the ability of mental structuring. In psychology and cognitive sciences, such systems of organising and perceiving new information or the mental structure of some pre-created ideas are described in the schemes. The cognitive scheme in Figure 6 describes a recognised pattern of thinking and behaviour of users in the interpretation of cartographic symbols for communication in a crisis in *Emergency Response Symbology, Canadian All-Hazards Symbology, Australian All Hazards Symbology* and *MIL-STD-2525D Common Warfighting Symbology*. The same template could be applied in sets *OCHA's Humanitarian Icons* and *Humanitarian Demining Map Symbols* in the case of their customisation for crisis mapping. Following such a cognitive scheme, the user uses logic in the interpretation of cartographic symbols on a crisis map that tells them that the graphic appearance of the symbol is divided into two parts: *frame*, which is to a certain extent a constant part of the cognitive scheme (that is, it receives the finite number of geometric shapes of certain colours), which frames the *pictogram* – a variable part of the scheme that takes on a new form every time. The user visually and/or logically interprets various forms of pictograms, and each shape associates with a particular object, phenomena or action. The frame around a pictogram is sometimes a red square, sometimes a blue rectangle, and in an unconscious process, the user's brain organises such objects into groups, by applying the similarity principle – similar objects form a group. The frame location on the map indicates the position of the displayed object relative to other objects on the map.

Apart from the quality, the identified objects can also be distinguished by their ordered properties. By analysing the existing cartographic symbol set, it was noted that the ordered property was not present in the first versions but was included in second editions of the sets *Australian All Hazards Symbology* and *Canadian All Hazards Symbology.* As a result, for example, infrastructure objects can always be distinguished as *destroyed* or *undamaged*, roads as *passable* or *impassable*.

It is obvious that, in the case of the map symbols for communication in a crisis, tradition, homogeneity, uniformity, and standardisation – both in the graphic design of symbols and in their application on crisis maps are crucial. Standardisation (in the sense of ensuring unambiguous and consistent application) of cartographic symbols on maps for communication and acting in a crisis would mean gradually adaptation of users to their meaning, thus making them more successful in use on the maps for communication in a crisis.

The *Emergency Response Symbology* is arguably the most globally recognised standardised approach to emergency management mapping symbology and is also formally recognised as an American National Standards Institute (ANSI) standard. As the *Emergency Response Symbology* was the pioneer symbology standard for emergency management, later attempts, including the *Canadian* and *Australian All-Hazards Symbology* sets, were inspired by the American forerunner and frequently try to build as much as possible on this system.

In addition to the graphical design of a particular cartographic symbol, it is necessary to provide to the crisis management participants (who are at the same time "cartographers" and users) rules and guidelines for the use on the map. To be able to expand the system with new symbols it is necessary to standardise guidelines for graphic design of cartographic symbols. The guidelines must specify the minimum size below which the readability of individual symbols will no longer be possible and predict the use of symbols on the maps of different scales since the scale dictates the size of the cartographic symbol and the amount of detail that can be represented by a pictogram on a particular symbol. We are aware that guidelines for determining the visual appearance of a particular symbol can only provide general notes, and the guidelines for obtaining good readability specific notes in the design of cartographic symbols. For this reason, people who will design new symbols should still have some (basic) knowledge of how to apply the given guidelines.

Apart from easy understanding and memorising, confirmation of the success of cartographic symbols is their availability and maximum ease of use on crisis maps that will only be created in the future. Incorporation of symbols in the software (e.g. symbols of the *Emergency Response Symbology* are available in ESRI's ArcGIS software), and uploading the symbols on platforms (for example, symbols from *OCHA's Humanitarian Icons* are available in the platform *The Noun Project*) can help in recognising the set as the de facto standard in the crisis and humanitarian community.

The results of this research showed that the current methods for public online sharing mostly include sharing via the organisation's website. Future research in the field of crisis mapping should seek to develop additional resources (such as crowdsourced, open-source web-based repositories and platforms for accepting, storing and disseminating symbols) that would further encourage the sharing of symbol sets among organisations and promote standardisation with regard to ensuring unambiguousness and the general and repeated use of these symbols on crisis maps.

It is necessary to put efforts in different forms of promotion, such as publishing, presenting, workshops, brochures, flyers, posters, conferences, and training activities. Sharing, promotion, dissemination and promulgation of the cartographic symbols undoubtedly imply investments such as costs of training, raising awareness, and changing standard practices and procedures. The establishment of funding mechanisms, as well as the establishment of a clear structure of management of implementation activities, should help in mitigating these costs.

https://doi.org/10.5194/isprs-archives-XLII-3-W8-241-2019

Relying on good practices in existing cartographic symbol sets for crisis mapping can also mitigate transition costs and encourage the adoption of existing symbol sets.

A comparative analysis has revealed that certain changes were implemented in new, reviewed or extended editions of existing sets. Better visual organisation is achieved in the *Canadian All Hazards Symbology* set, special symbols for expressing associative and selective properties are added in *Canadian* and *Australian All Hazards Symbology* sets, learning and training materials like demonstrative examples of using symbols on maps are provided with *Emergency Response Symbology* and *Canadian All-Hazards Symbology*, graphical guidelines are made for extending the *OCHA's Humanitarian Icons* set. Hopefully, the results of this comparative analysis of prominent cartographic symbols for crisis mapping can be of assistance to less unified and coherent standards and symbologies currently in use, many of which, though they have not been standardised yet, still have important information to convey.

ACKNOWLEDGEMENTS

This work has been fully supported by the Croatian Science Foundation under the project number IP-01-2018-8944.

REFERENCES

Akella, M. K., 2009: First responders and crisis map symbols: Clarifying communication. *Cartography and Geographic Information Science*, Vol. 36, No. 1, 19–28.

ANSI, 2006: ANSI INCITS-415 2006 Homeland Security Mapping Standard – Point Symbology for Emergency Management Washington, DC: American National Standard for Information Technology.

Bianchetti, R.A., Wallgrün, J.O., Yang, J., Blanford, J.I., Robinson, A.C., and Klippel, A., 2012: Free Classification of Canadian and American Emergency Management Map Symbol Standards. *The Cartographic Journal* 49 (4) pp.350–360. doi.org/10.1179/1743277412Y.0000000022.

Cabinet Office, 2012. Cabinet Office with the Ministry of Defence and the Ordnance Survey. Civil Protection Common Map Symbology, https://www.ordnancesurvey.co.uk/support/symbols-for-emergencies.html (Accessed 10 June 2019).

DOD, 2014. MIL-STD-2525D 10 JUNE 2014, Interface Standard Joint Military Symbology, Department of Defense, Washington, DC.

Dymon, U. J., 2003: An analysis of emergency map symbology. *International journal of emergency management*, Vol. 1, No. 3, 227–237.

EMSINA, 2019. Emergency Management Spatial Information Australia: Australian All Hazards Symbology Version 2 – 2018, https://www.emsina.org/allhazardssymbology (Accessed 10 June 2019).

GICHD, 2005. Geneva International Centre for Humanitarian Demining, Cartographic Recommendations for Humanitarian Demining Map Symbols in the Information Management System for Mine Action (IMSMA).

GOC, 2015. Government of Canada's Government Operations Centre: Canadian All-Hazards Symbology. https://www.publicsafety.gc.ca (Accessed 10 June 2019).

INDIGO, 2012. INDIGO project Crisis Management Solutions. European Emergency Symbology reference for 2D/3D maps developed within the INDIGO project, http://indigo.diginext.fr (Accessed 10 June 2019).

Kostelnick, J. C., Dobson, J. E., Egbert, S. L., Dunbar, M. D., 2008: Cartographic symbols for humanitarian demining. *The Cartographic Journal*, Vol. 45, No. 1, 18–31.

Kostelnick, J., Hoeniges, L., 2018: Map Symbols for Crisis Mapping: Challenges and Prospects. *The Cartographic Journal.* 56. 1–14. doi.org/10.1080/00087041.2017.1413810.

Marinova, S. T., 2018: New Map Symbol System for Disaster Management. *Proc. Int. Cartogr. Assoc., 1, 74*, https://doi.org/10.5194/ica-proc-1-74-2018, 2018.

MacEachren, A. M., 1995: How maps work: Representation, visualization and design. Guilford, New York.

Robinson, A.C., Pezanowski, S., Troedson, S., Bianchetti, R.A., Blanford, J.I., Stevens, J., Guidero, E., Roth, R.E., MacEachren, A.M., 2013: Symbolstore: A Web-Based Platform for Sharing Map Symbols. *Cartography and Geographic Information Science* 40 (5), 415–426. doi.org/10.1080/15230406.2013.803833

Robinson, A. C., Roth, R. E., MacEachern, A. M., 2010: Challenges for map symbol standardization in crisis management. *Proceedings of the 7th International ISCRAM Conference*, Seattle, USA, May 2-5, 2010, 1–5.

The Noun Project, 2014. The Noun Project. https://thenounproject.com (Accessed 10 June 2019).

UN OCHA, 2012. United Nations Office for the Coordination of Humanitarian Affairs. World: Humanitarian and Country Icons 2012. http://reliefweb.int/report/world/world-humanitarian-and-country-icons-2012 (Accessed 10 June 2019).

UN OCHA, 2018. United Nations Office for the Coordination of Humanitarian Affairs. Humanitarian and Country Icons 2018. https://reliefweb.int/report/world/humanitarian-and-country-icons-2018 (Accessed 10 June 2019).

URL1: Emergency Response Symbology, https://www.fgdc.gov/HSWG (Accessed 10 June 2019).

URL2: Canadian All-Hazards Symbology, http://216.254.169.195/CAHS_SCTR (Accessed 10 June 2019).

URL3: Australasian All Hazards Symbology, https://www.emsina.org/allhazardssymbology, (Accessed 10 June 2019).

URL4: Military Symbols for Land Based Systems, http://www.mapsymbs.com/ms2525c.pdf, (Accessed 10 June 2019).

URL5: Geneva International Centre for Humanitarian Demining, https://www.gichd.org (Accessed 10 June 2019).

https://doi.org/10.5194/isprs-archives-XLII-3-W8-241-2019 | © Authors 2019. CC BY 4.0 License.