KINEMATIC MODELING FOR THE SEISMIC AND TSUNAMI EARLY WARNING SYSTEMS – BULGARIAN EXPERIENCE

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"Megaearthquakes and tsunamis in subduction zones"

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General physical considerations for the kinematic models:

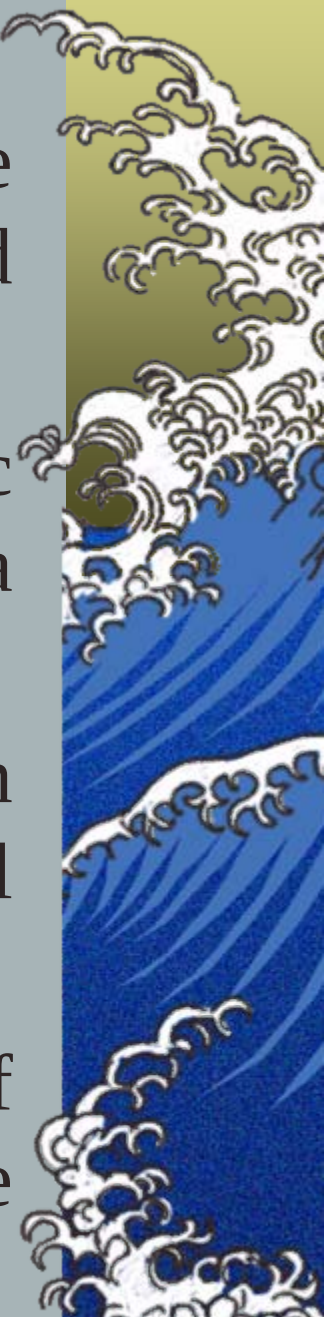
- *Seismic waves - high velocities –7-8 km/s.*
- *Tsunami waves - lower velocity –*

between 40-800 km/h.

- *The time difference between the tsunami and the seismic waves is in the range of 10*2 to 10*4 of seconds.*
- *High effective tsunami warning systems*

Active Projects related to the EWS in Bulgaria (list, aim, time)

- MARINEGEOHAZARDS (focused on marine hazards in the Black Sea – earthquakes and tsunamis).2010-2013
- DACEA (about possibility of Vrancea seismic source earthquakes to be warned in Bulgaria and Romania). 2011-2013
- ESNET (about support of decision makers in case of earthquakes and other coastal hazards).2012-214
- SIMORA (about a local monitoring system of strong ground motions and its relevancy to the EWS).2012-2014



WEBs of the projects

- MARINEGEOHAZARDS

http://www.geohazard-blacksea.eu/project.html

Newsletter – 6 issues

- DACEA

http://www.infp.ro/news/dacea-project

- ESNET

www.blacksea-esnet.eu

- SIMORA

http://simor0.wix.com/project

GOVERNMENT OF ROMANIA

MARINEGEOHAZARD

BLACK SEA EARLY-WARNING SYSTEM

Project MARINEGEOHAZARDS

ROMANIA - BULGARIA

Cross Border Cooperation Programme

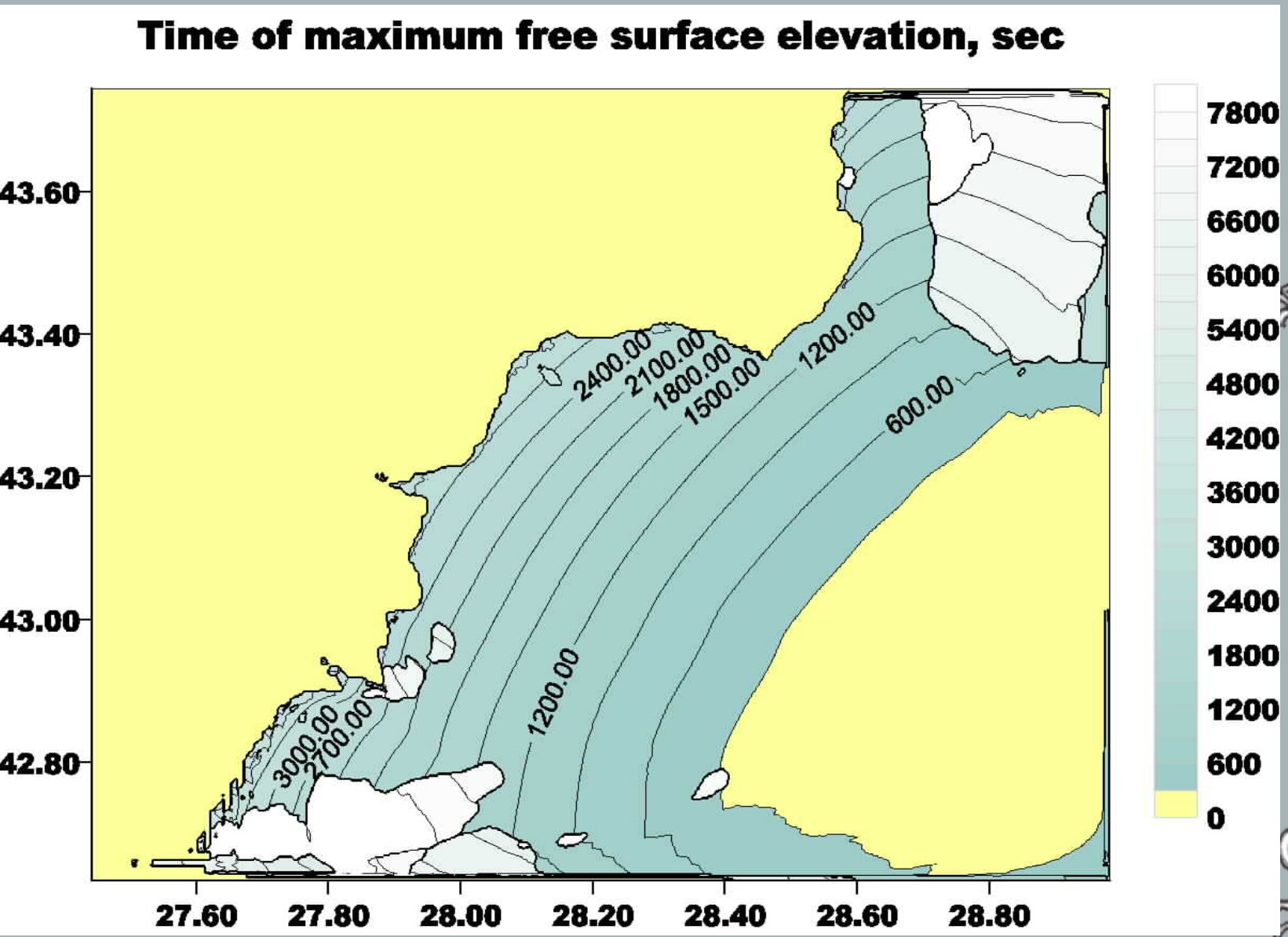
Common borders. Common solutions.

Project MARINEGEOHAZARDS

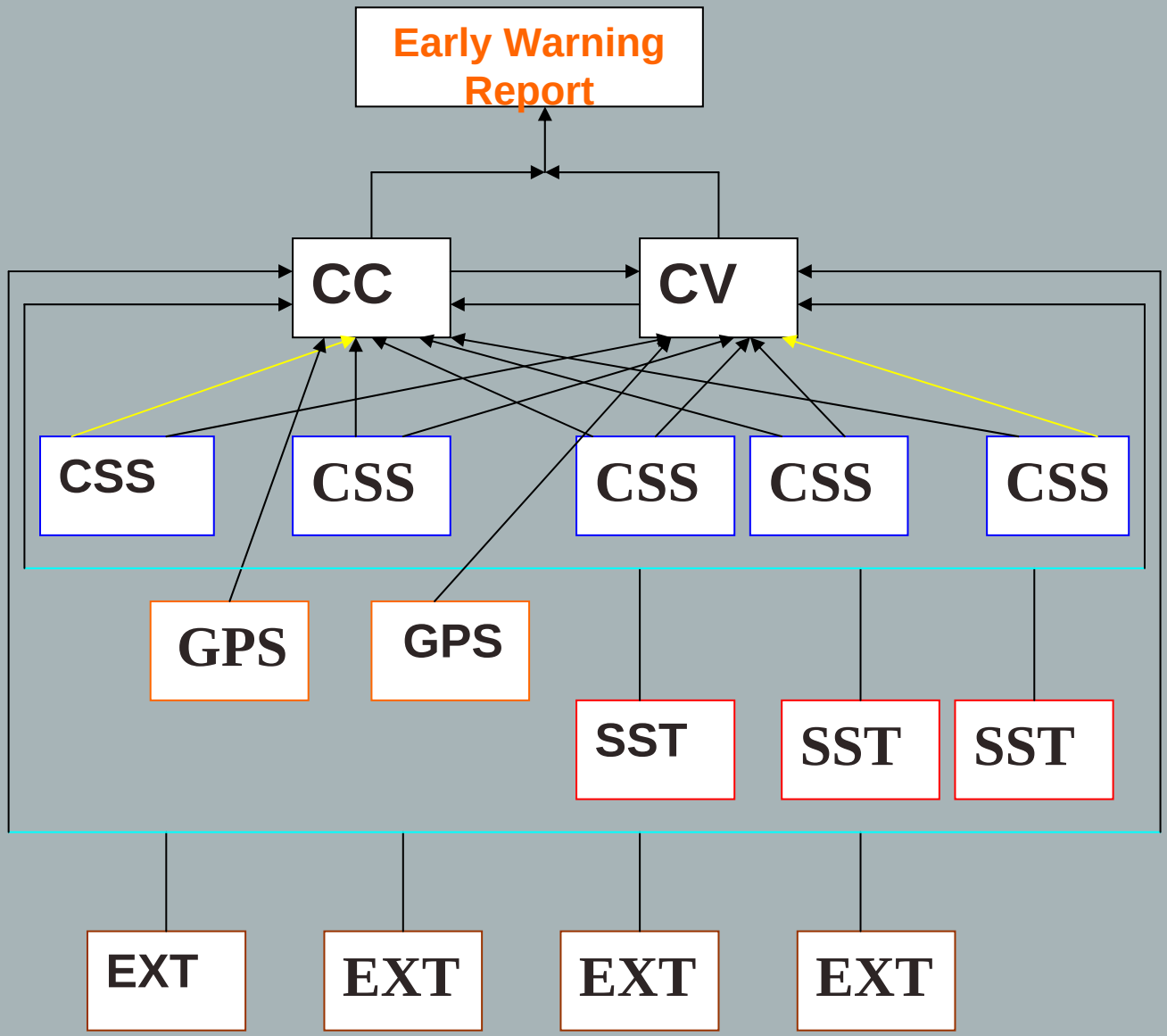
- *Coordinator:* ***GeoEcoMar***
- *4 partners:*
- ***GeoEcoMar, National Institute of Earth Physics (ROM);***
- ***Geological Institute, Institute of Oceanology (BAS-BG)***

Bulgarian sea and land stations and the tsunamigenic seismic source

Travel time of the maximum water elevation kinematics' assessment



SCHEMA OF THE MARINEGEOHAZARDS EQUIPMENT AND COMMUNICATIONS



SCHEMA OF THE MARINEGEOHAZARDS EQUIPMENT AND COMMUNICATIONS – Legend

- ***CC – Centre Constanta***
- ***CV – Centre Varna***
- ***Both Centers are equivalent***
- ***LEGEND***
- ***CSS – Complex Sea Station***
- ***SST – Strong motion Station***
- ***GPS – GPS Station***
- ***EXT – Extensometer Station***
- ***SAT – Satellite communication***
- ***INT – Internet Communication***
- ***COLORS***
- ***Dark Blue – SEA MODULE***
- ***All other colors – LAND MODULE***
- ***Yellow – Satellite Communication***
- ***Light blue – INTERNET***
- ***Early Warning Report***

The network equipment

- *2 data centers: Varna and Constanta*
- *Seismic networks:*

- Romania, Bulgaria national seismic networks

- *Strong motion devices (SMD) on coastal area*
- *Complex Bottom Stations*

- (CBS=OBS+DART)

- *GPS (GNSS) networks:*

- Bulgaria (4), Romania (14) GNSS + the national networks

- Local GPS networks

- *EXT – Extensometers network*

- Bulgaria local network

Decision Matrix for the tsunami warning – three levels of alert

Principles: Combinations = Convolution:

Green +green=green

Domination of the higher degree (CBS is essential):

Orange + orange=red

Green + orange = orange

Green + red = red

Orange+ red=red

SMD	CBS	GPS		EXT		Tsun warning
green	green	green	red	green	red	green
orange	green	green	red	green	red	green
red	green	green	red	green	red	orange
green	orange	green	red	green	red	orange
orange	orange	green	red	green	red	red
red	orange	green	red	green	red	red
green	red	green	red	green	red	red
orange	red	red		green	red	red
red	red	red		red		red

Physical fundamentals for the seismic EWS used in Bulgaria

Seismic waves - kinematics:

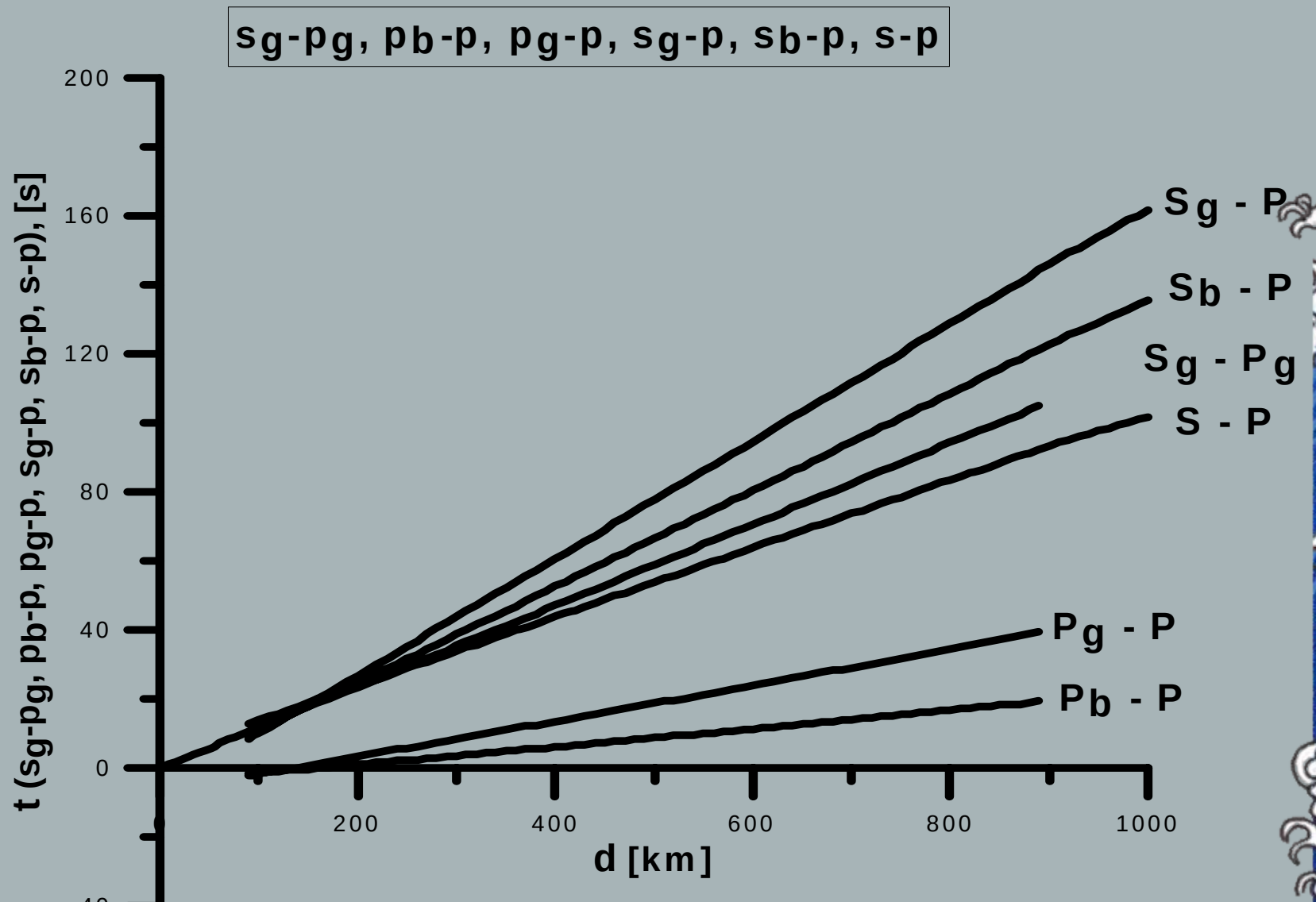
- *Ts/Tp - [Vs/Vp = 2*(1/2)] (d=const)*
- *The main relationships:*
- *Travel times:*
- *Tp(d), called "signaling" – the fastest phase*
- *Ts(d) - the most destructive phase*
- *Ts-Tp (d) (main basic equation of the SEWS) – called "warning time interval"*
- *Travel times curves – the basics of kinematic EWS*

Project DACEA

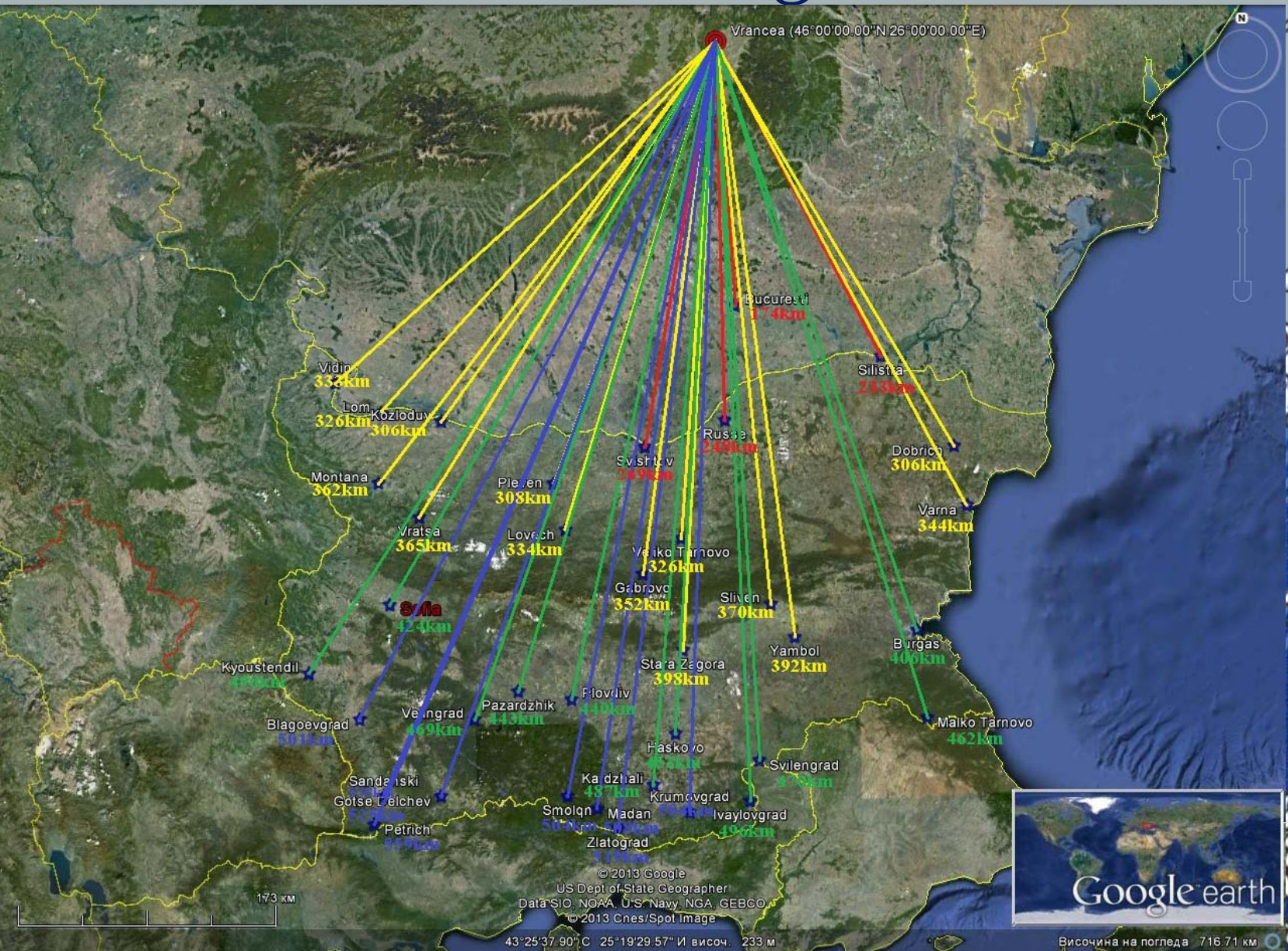
DAnube Cross-border system for Earthquakes Alert

- ***Project Coordinator:***
- *National Institute of Research and Development for Earth Physics*
- ***4 Partners:***
- *NATIONAL INSTITUTE OF GEOPHYSICS, GEODESY AND GEOGRAPHY OF BAS*
- *„OLTENIA" DOLJ COUNTY INSPECTORATE FOR EMERGENCY SITUATIONS,*
- *Association of the Danube River Municipalities "Danube",*
- *The Foundation for Democracy, Culture and Liberty, Calarasi Branch*

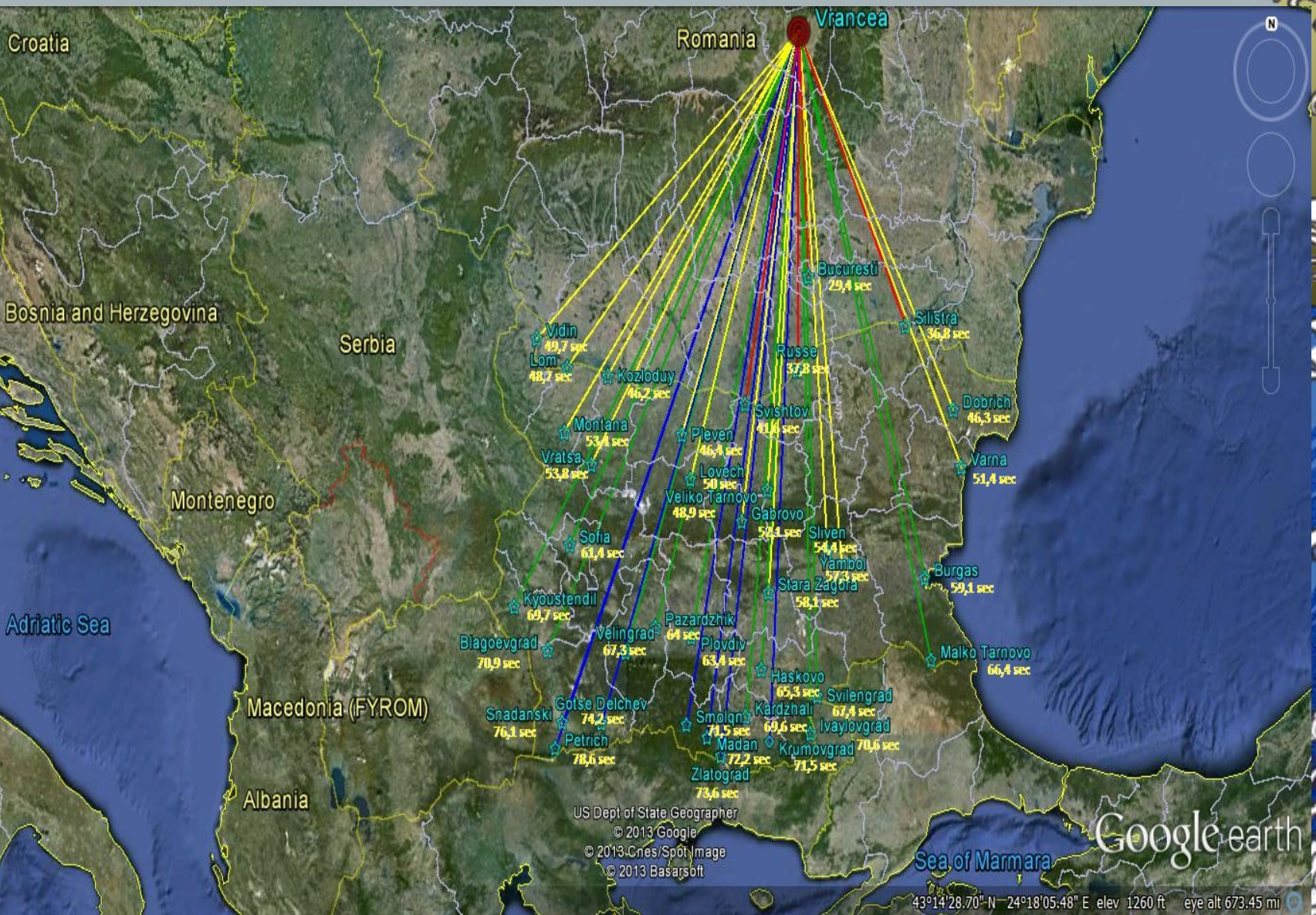
Standard travel times Tp ("signaling") and Ts – Tp ("warning") times



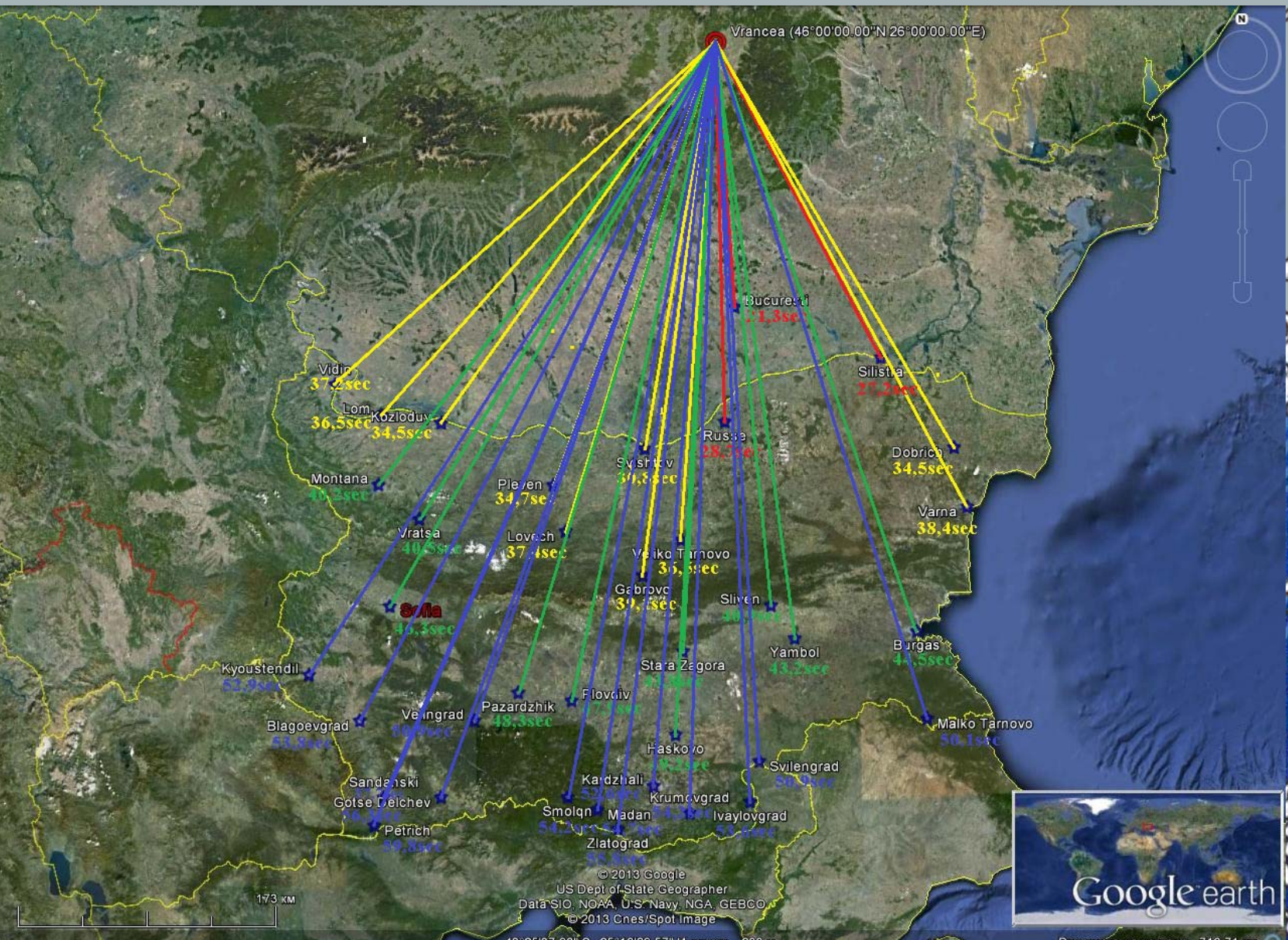
Distances from Vrancea seismic source to some Bulgarian cities



Tp travel times from Vrancea seismic source to some BG cities



Ts-Tp travel time for some Bulgarian cities – Vrancea source



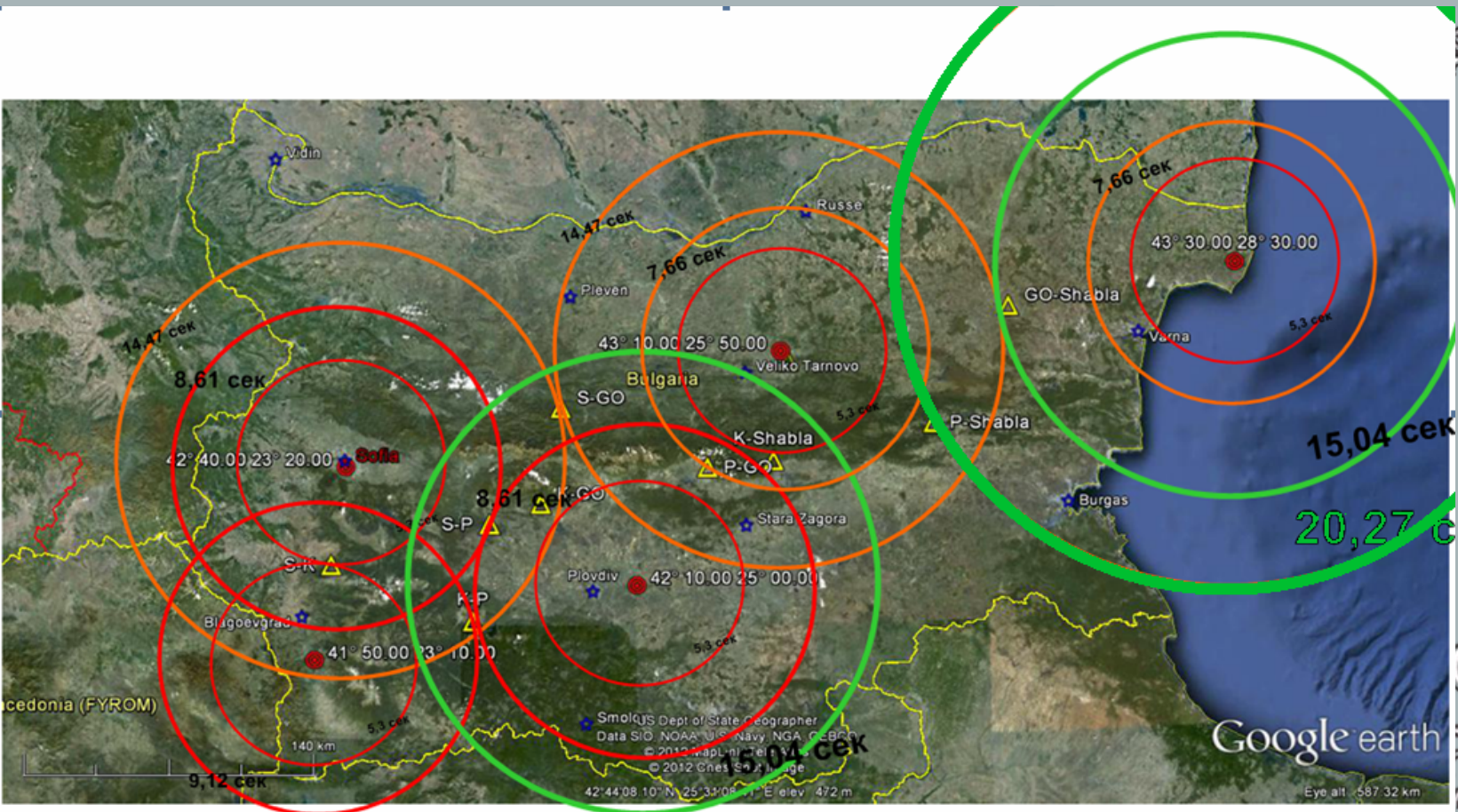
A model of the main seismic sources in Bulgaria

№	Seismic source	Coordinates		Depth
		ϕ [E]	λ [N]	[km]
1	Sofia	23°20'00"	42°40'00"	10
2	Kresna	23°10'00"	41°50'00"	10
3	Plovdiv	25°00'00"	42°10'00"	10
4	G.Oriahovica	25°50'00"	43°10'00"	10
5	Shabla	28°30'00"	43°30'00"	10

The Ts-Tp isochrones (in seconds) of each seismic source. Lines at the levels 5.3 (dark red), 7.6 (light orange), 8.6 (red), 14,5 (orange) 15 (light green) and 20,2 (green)

(They cover almost the entire territory of Bulgaria).

The red dots represent the main



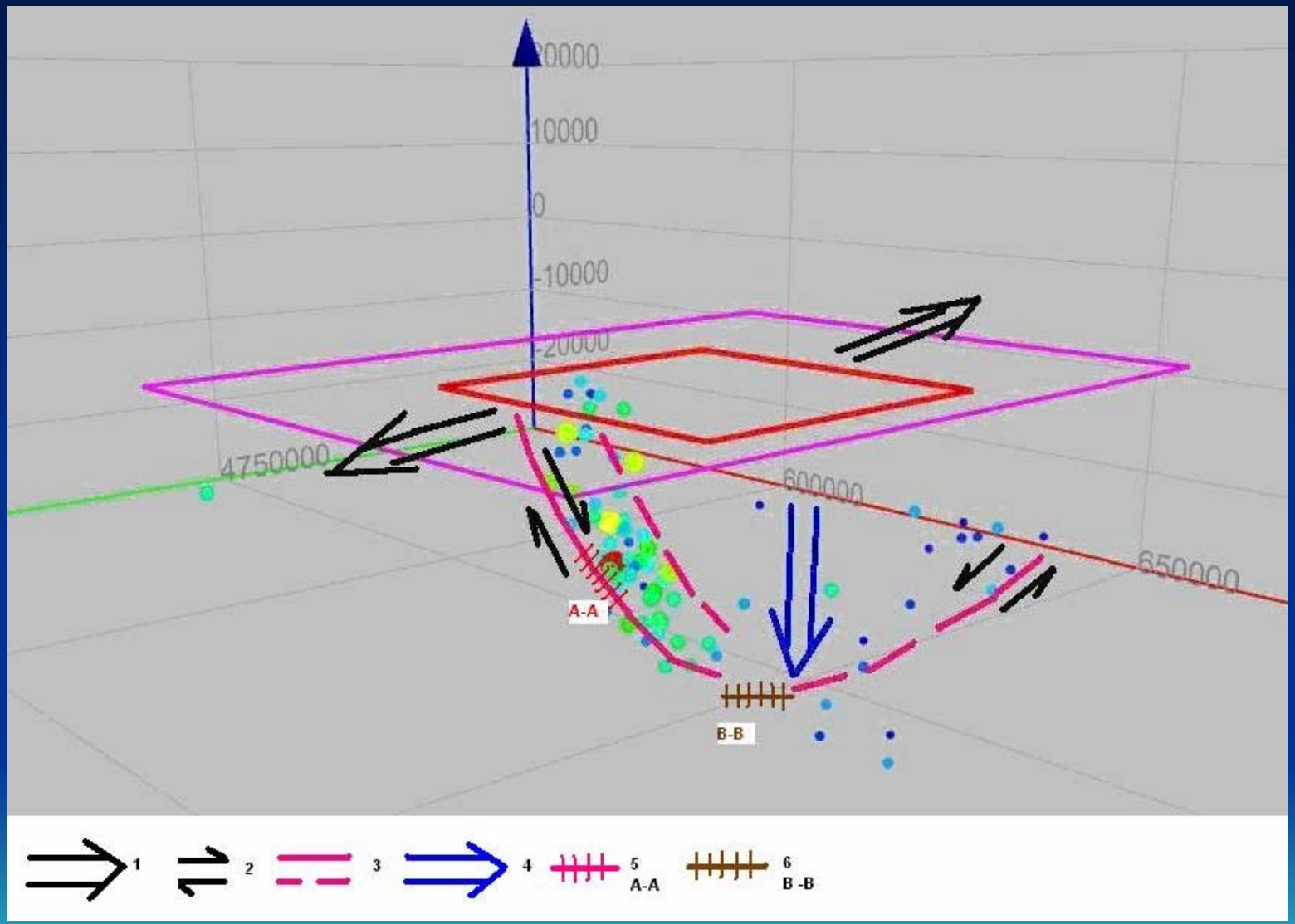
Project SIMORA – Seismic Monitoring and early warning system about Pernik city

- *National funding – 2013-2014*
- *Coordinator and partners - Mining and Geology University team*
- *Beneficiaries - Local authorities*
- *International cooperation*
- *Duration – 24 months*

General objective

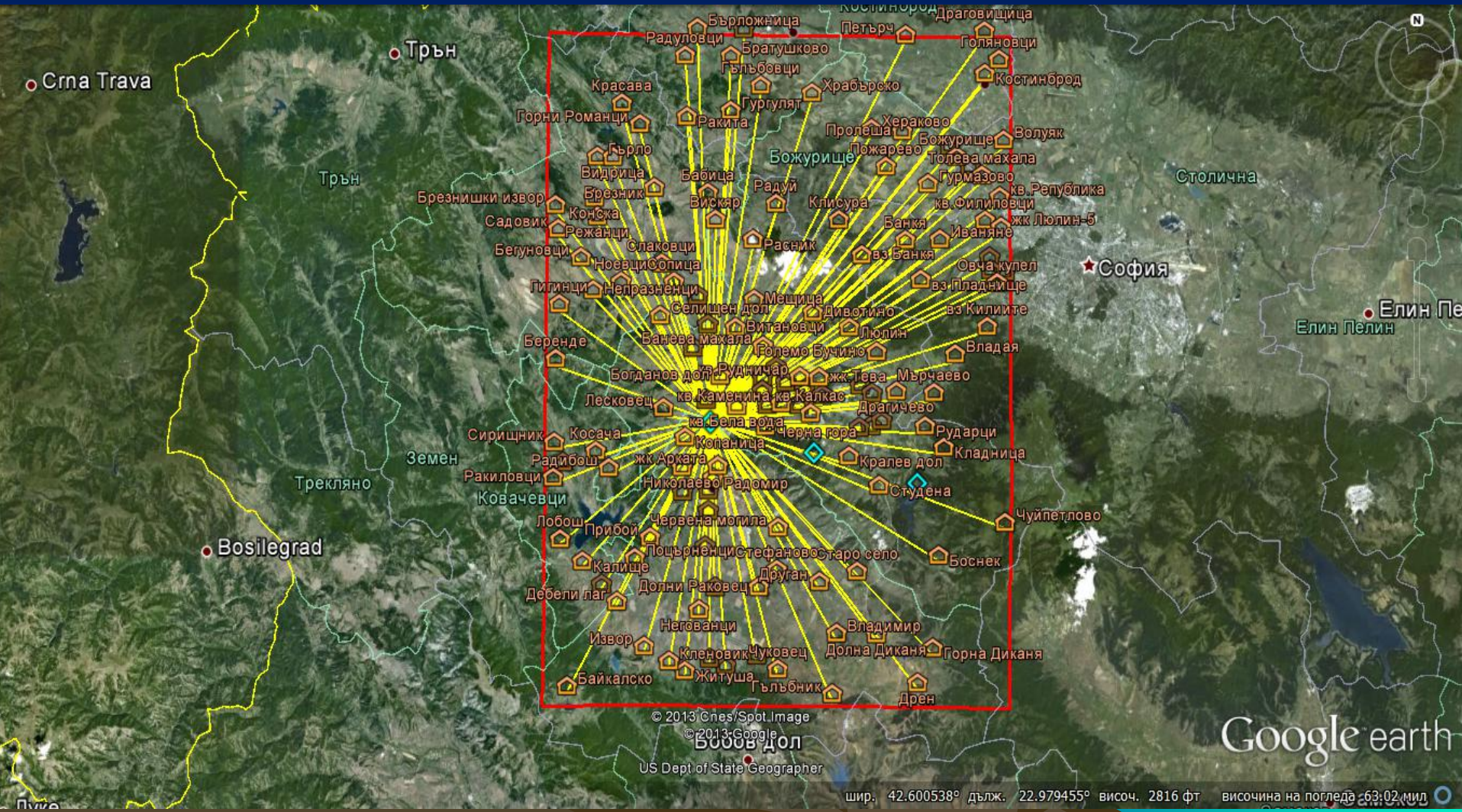
- *To create a strong motion monitoring system in the area affected by a moderate earthquake – M5.8 – 22nd May, 2012 and to provide local authorities with reliable quantitative information about the level of strong ground motions.*

3D Seismotectonic model

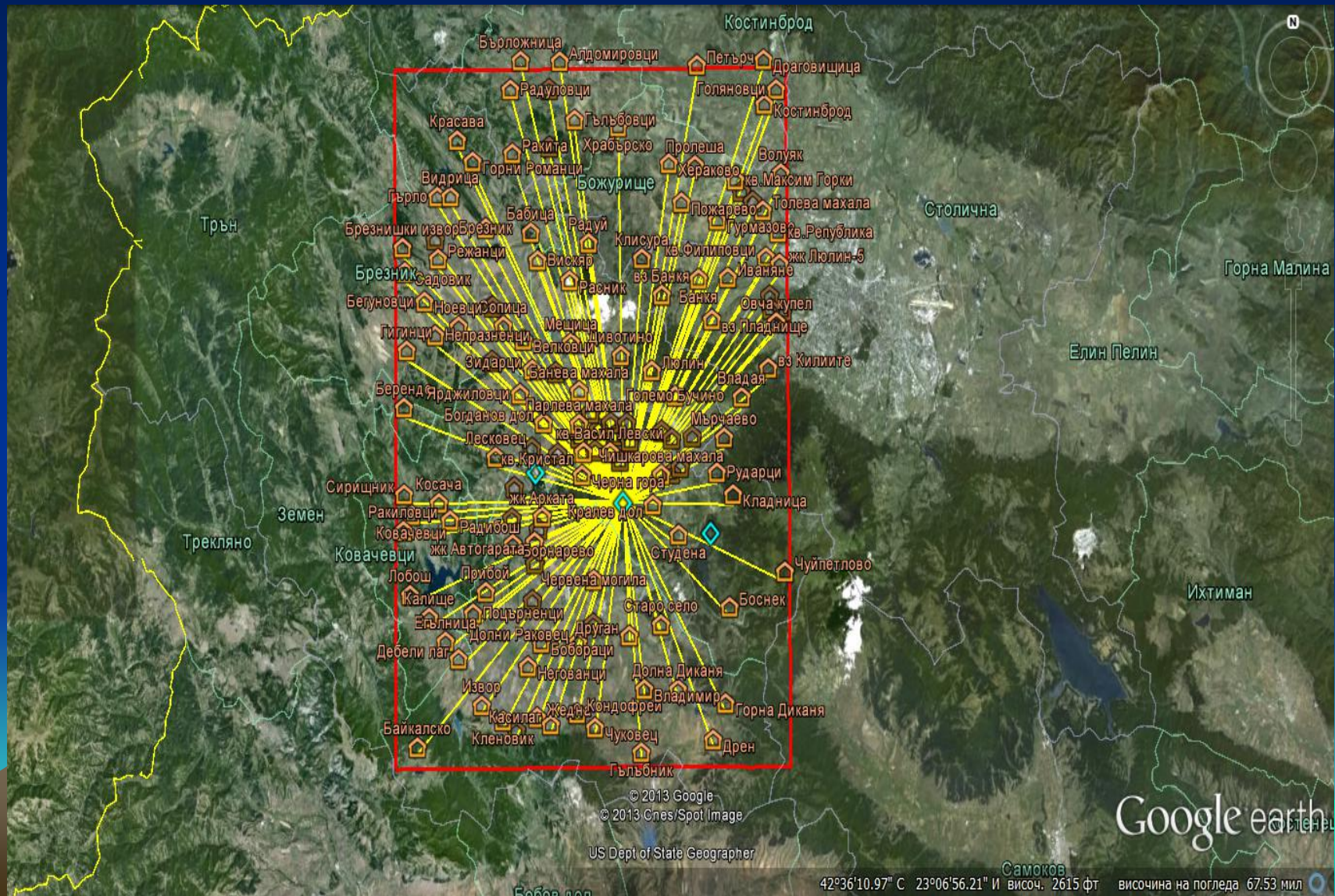


- 1 – extension; 2 – downward movements of the subsided block; 3 – listric faulting;
- 4 – direction of the subsidence; 5 – areas of destruction during the main shock (and aftershocks) – considered as source of high frequencies; 6 – lowest part of the subsided block – considered as source of the low frequencies.

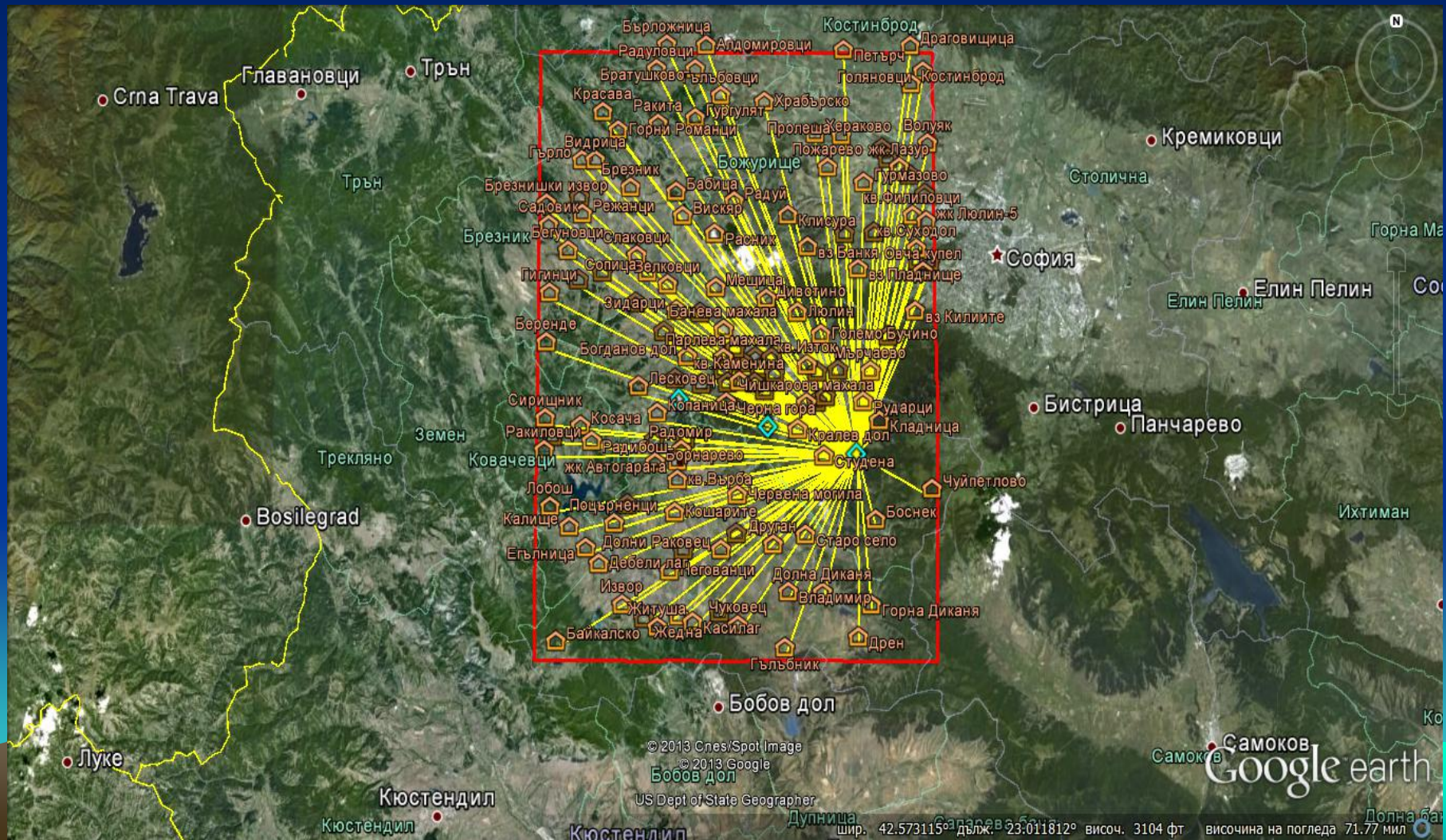
Distances to the villages in Pernik area (left source point) - between 0 and 32 km (respective Tp – 0-6.5 sec)



Distances to the villages in Pernik area (middle source point) – between 0 and 28 km (respective Tp – 0-5.8 sec)



Distances to the villages in Pernik area (right source point) – between 0 and 38 km (respective Tp – 0-7.2 sec) – low expected efficiency of the warning issue



Kinematic model SEWS (Pernik)

- Intentions:
- Amplitude discrimination
- System triggered by every single device
- More signalization then warning
- Data acquisition for further processing

- Tables for travel times of P and S waves from each source point to each village

Initial steps to the EWS in BG – kinematic simulations

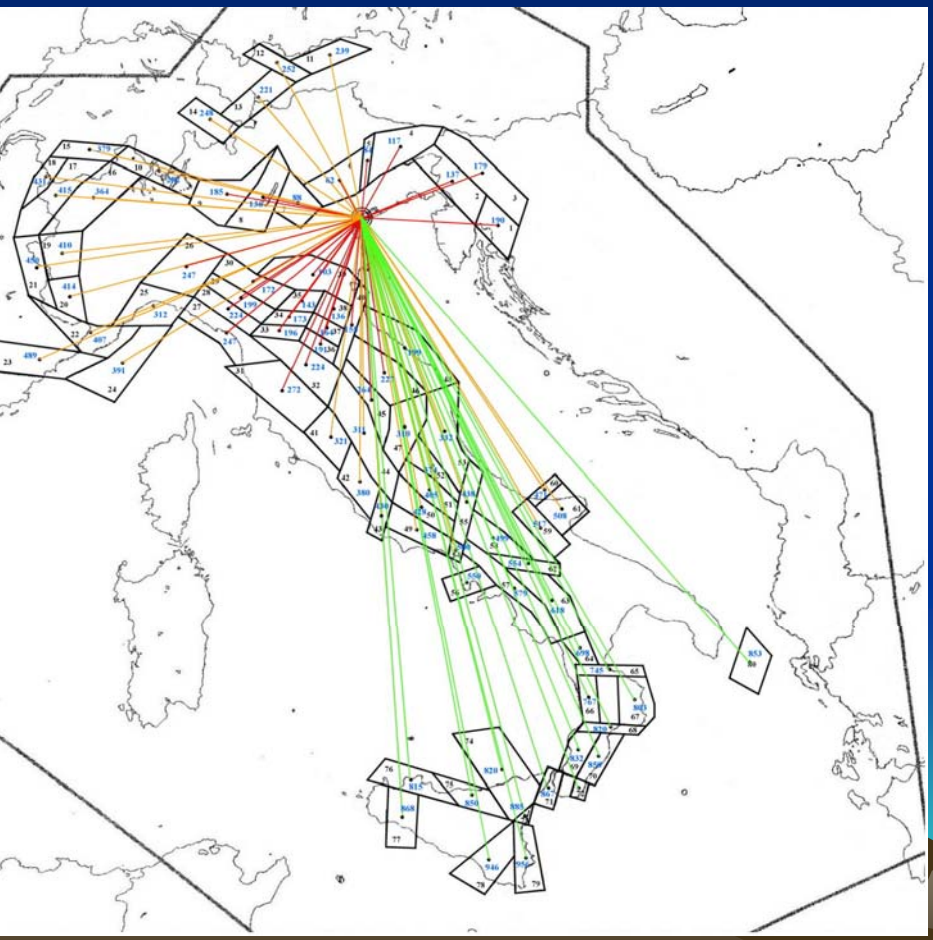
- Initial steps – kinematic models
- Legislation issues
- Application purposes:

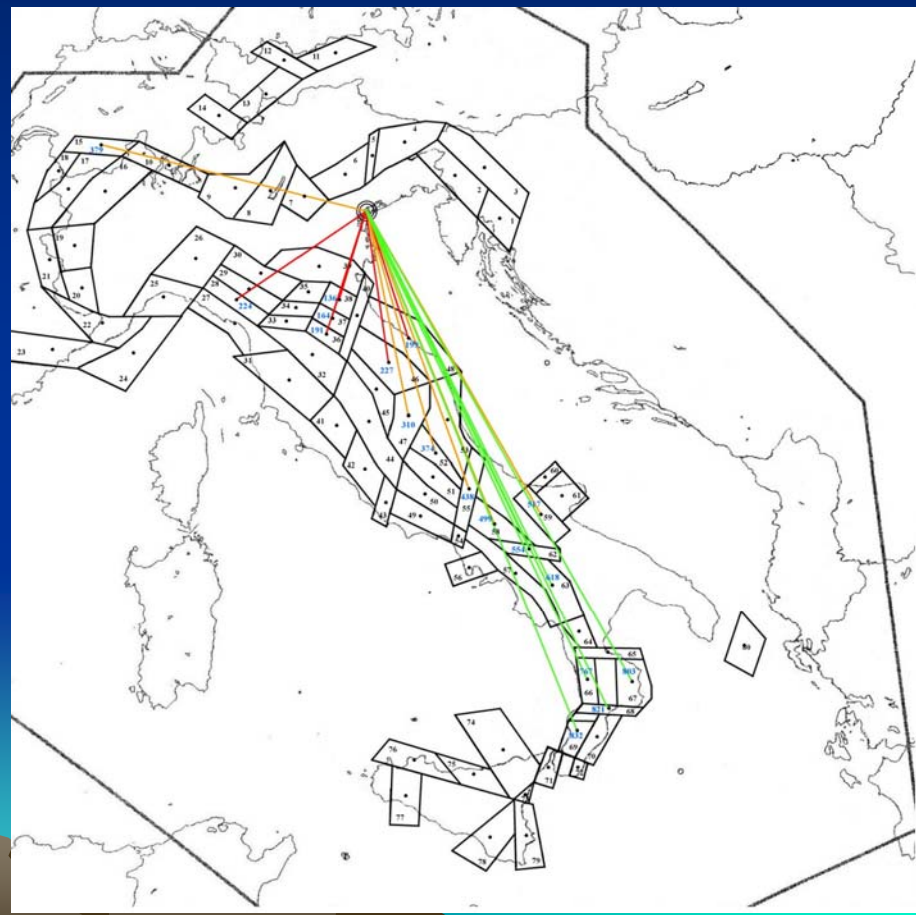
(example - Black Sea ecology) and institutions

- Maintenance and upgrade
- The Venice case (in frame of the ANDROID network)

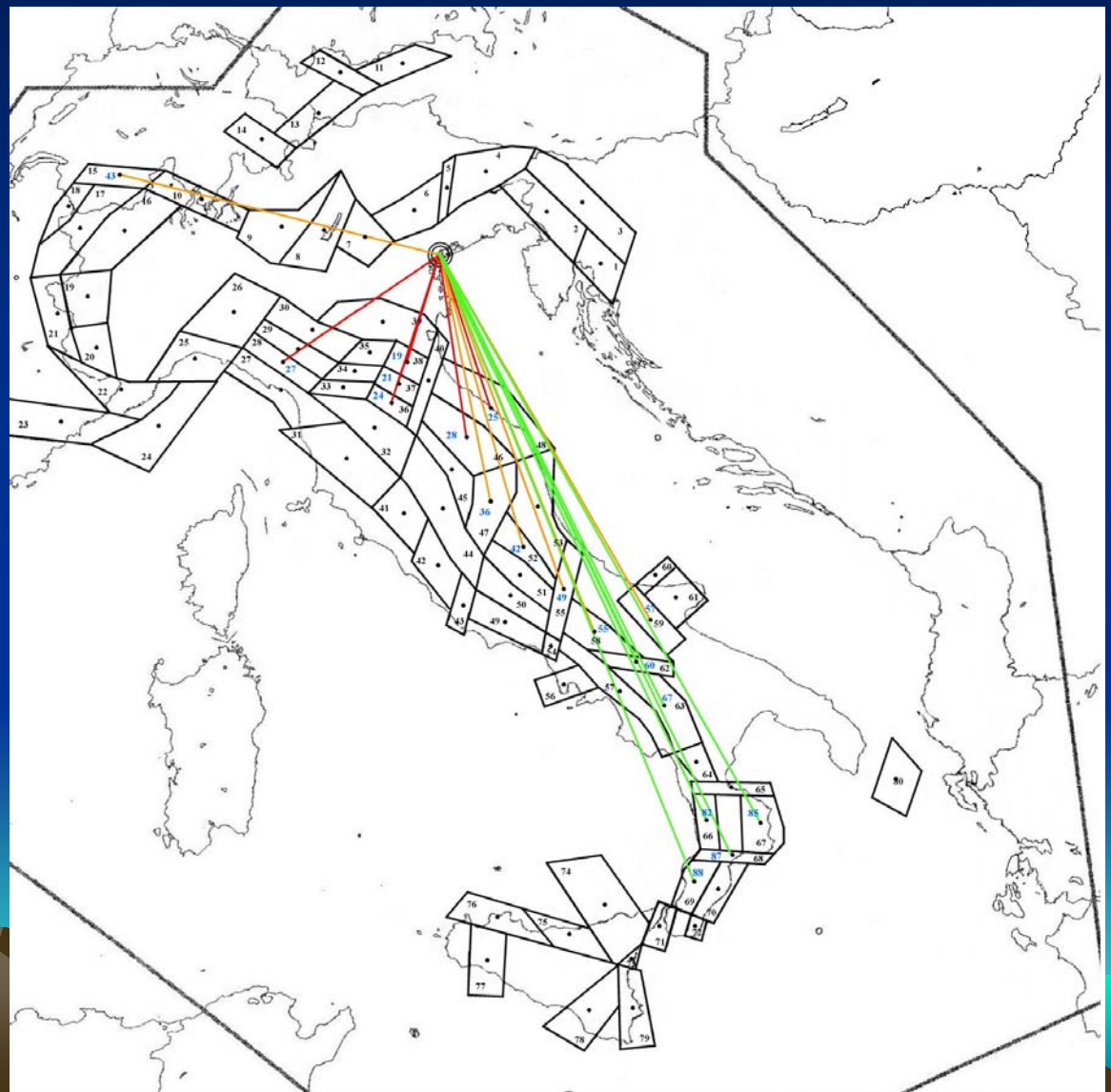
Venice case – kinematic models

- *Seismotectonic sources of Italy according (Slejko et al, 1998) and distances between them and Venice.*
- *B) Distances between the high active seismic sources Venice.*

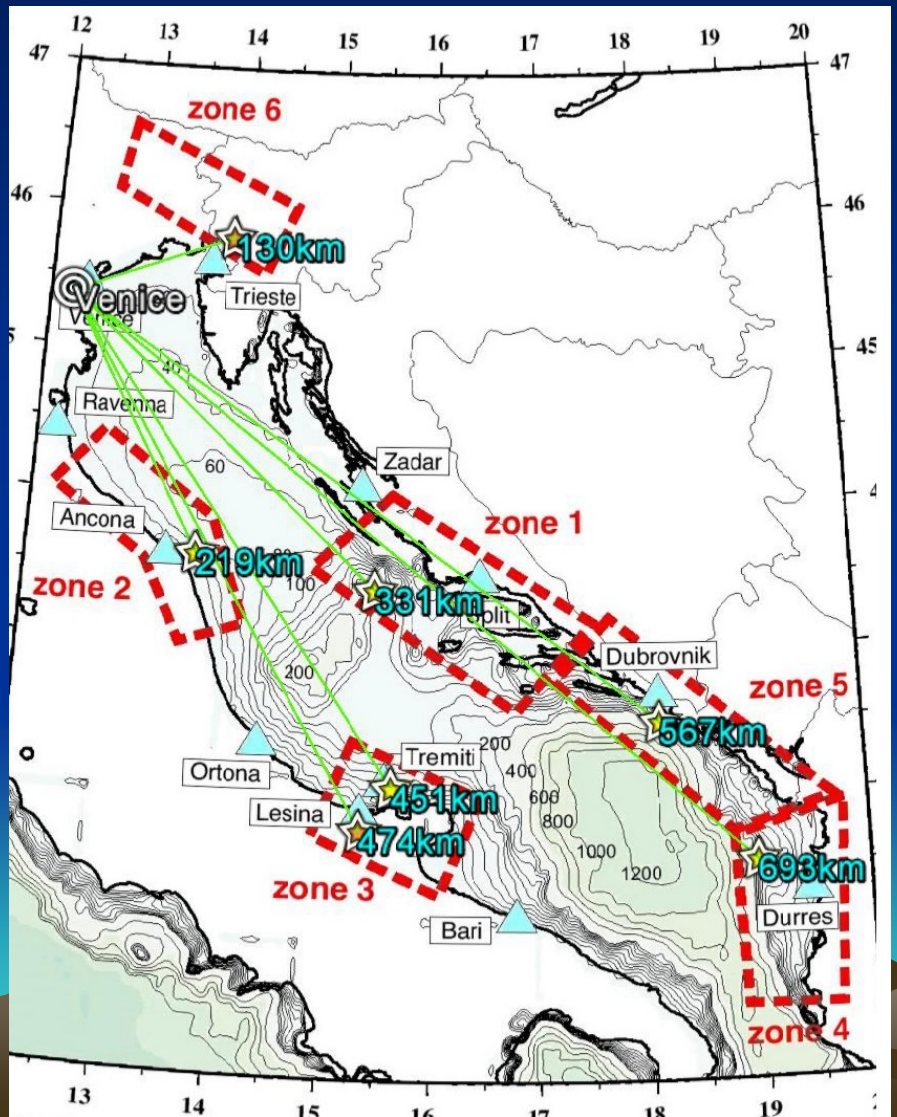


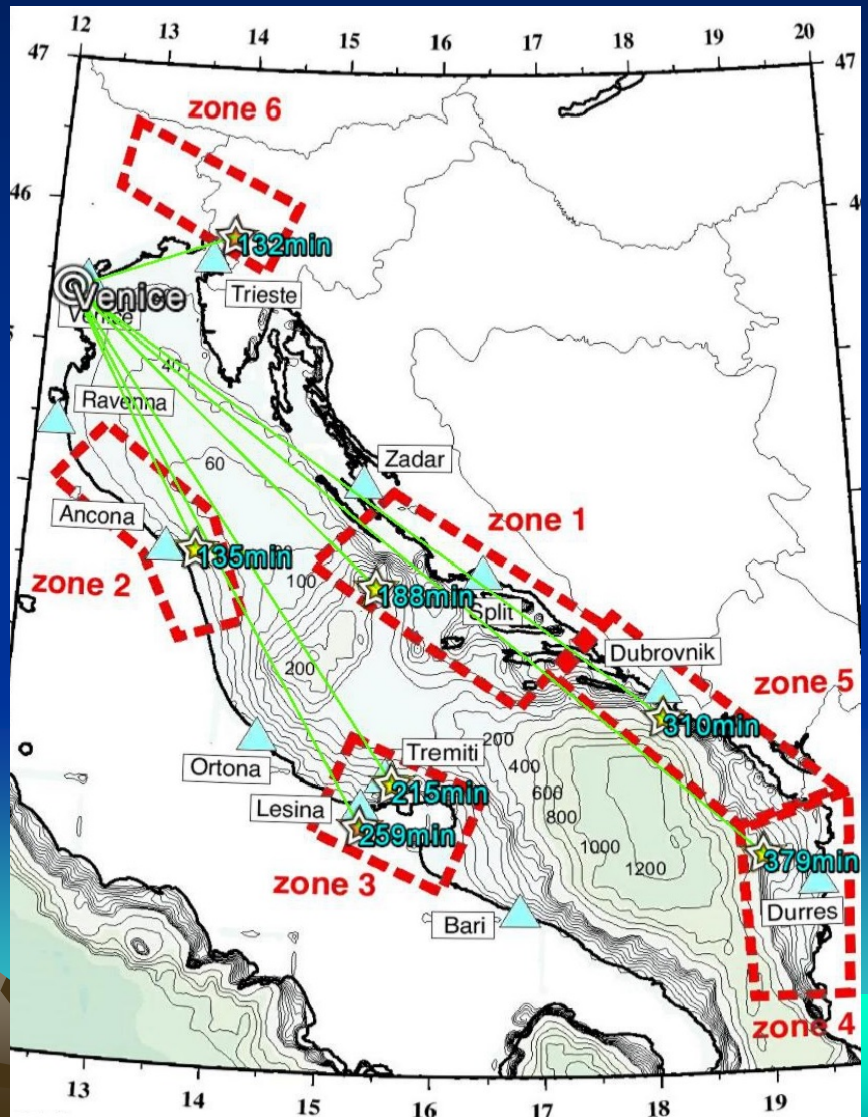


Ts-Tp warning times for Venice



Tsunami sources distances and travel times to Venice.





THANK YOU FOR YOUR ATTENTION!

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