teamnet transforming technology

PROJ4 Issues
The case of Romania: increasing transformation accuracy through grid shift files

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Outline

- National Reference System of Romania
- Reference transformation: TransDatRo
- Current implementations
  - Open source software
  - Proprietary software
- Towards increased precision (in FOSS)
- Conclusion

1

Romanian National Projection System

Romanian National Projection System

- S-42 National Reference System – “Stereo70”
- Characteristics:
  - Krasovski 1940 ellipsoid
  - Stereographic projection “1970”

Transformation issues

- No simple mathematical formula
- Existing attempts produce inconsistent errors, with accuracy depending on actual location of the dataset
- Reprojection to/from other systems result in topological errors

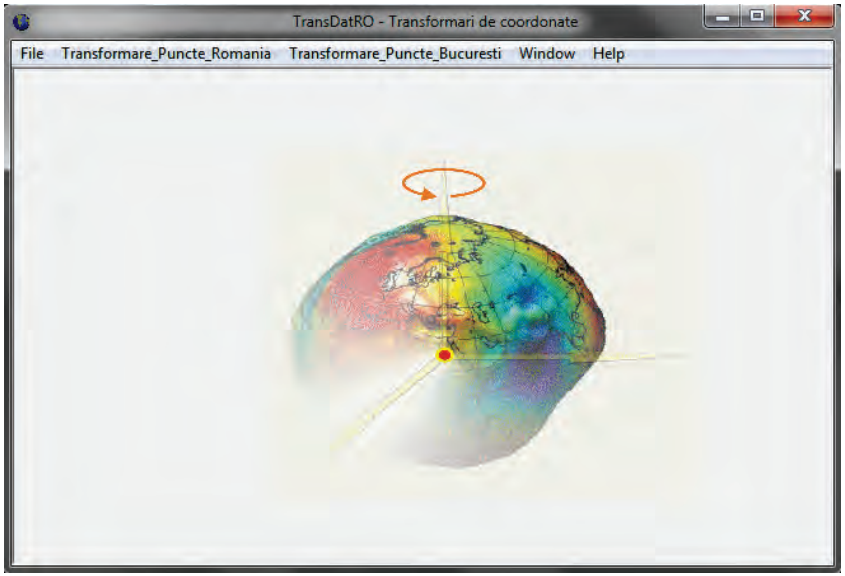
Why bother with it

- *De jure* standard for topo-geodesic measurements
- Large existing database of geographic information using the projection (both classical maps and GIS systems)
- *Regulation No. 1089/2010 (EU) on the implementation of the INSPIRE directive as regards interoperability of geodatasets and services* recommends using ETRS89

2

Reference transformation: TransDatRo

TransDatRO



- “Dumb” application provided by the Romanian Cadaster Agency (ANCPI)
- Reprojects from/to ETRS89 (LAEA and Transverse Mercator projections available)
- Declared planimetric precision: ±10+15 cm

Algorithm

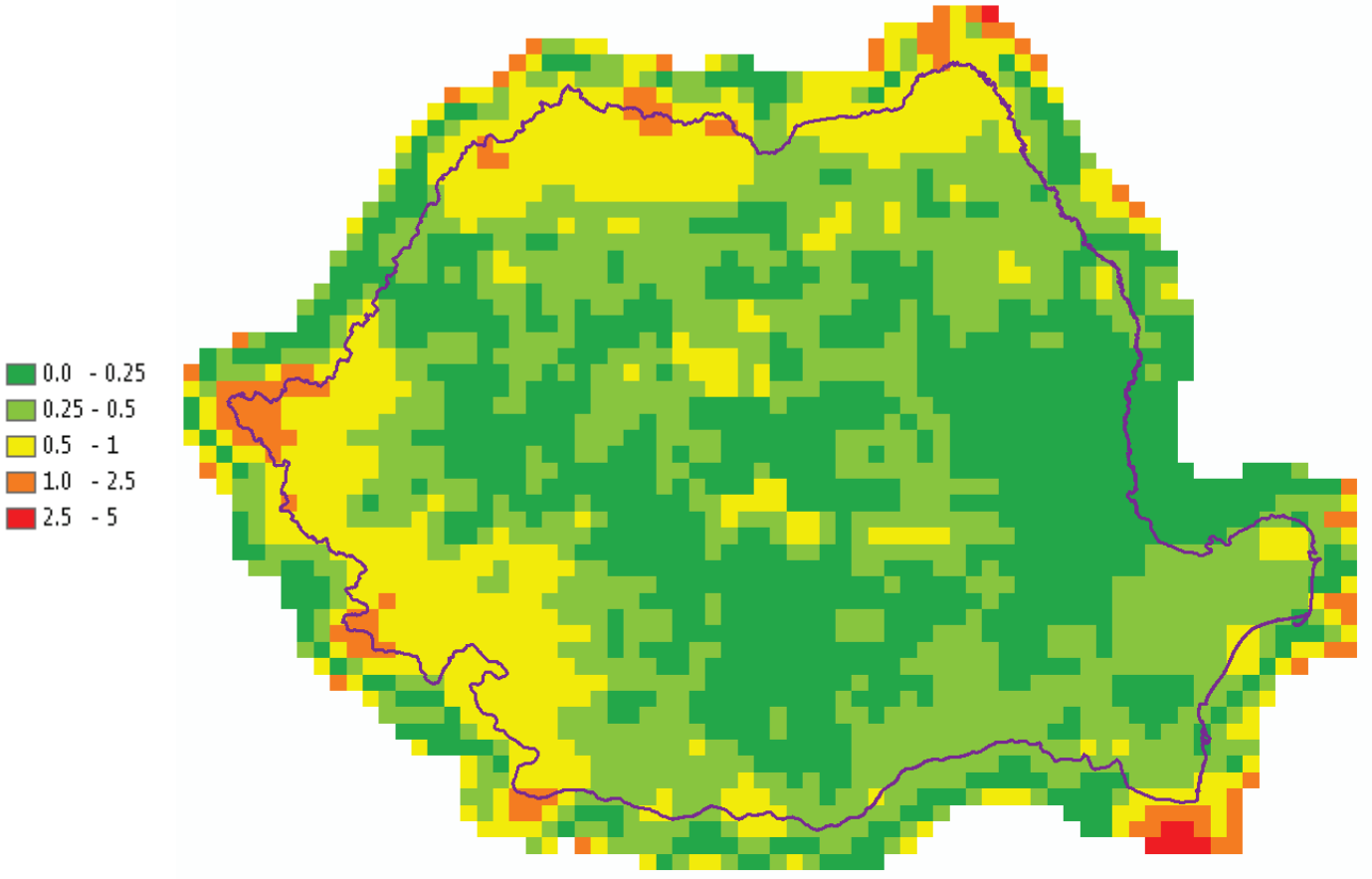
1. Convert ETRS89 ellipsoidal coordinates to Cartesian coordinates in the oblique stereographic projection

2. Convert GRS80 coordinates to Stereo70 coordinates

3. Interpolate geometric correction based on a table of datum shifts

4. Interpolate quasigeoid anomalies to account for the Black Sea reference altitude (Marea Neagră 1975 system)

TransDat v.1.02
absolute horizontal datum shifts



Limitations

- MS Windows only
- “Experimental” source code for version 1.0
- Accepted input format:
  - ESRI Shapefile (v1.0)
  - Text files (v4)
- Cumbersome UI

3

Alternative transformations: Open Source Software

PROJ.4

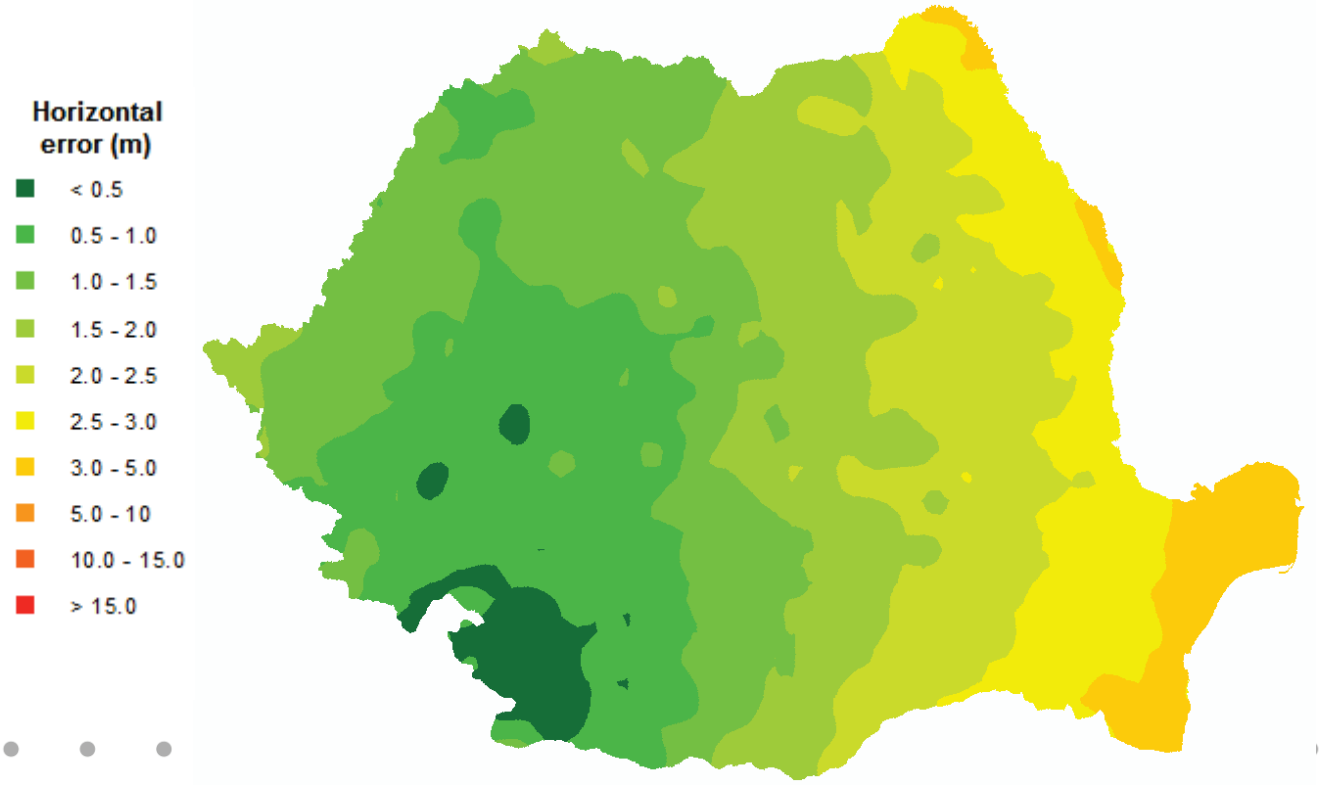
- FOSS library available for most major OSs
- A large database of global, national and local projection systems
- WGS84 as intermediary projection system
- Used for reprojecting in a large part of higher-level open-source GIS software

Stereo70 ?!?

- No standard EPSG code
- Several potentially applicable codes (originally from the GeoTIFF library)
  - EPSG:31700
  - EPSG:3844
  - EPSG:4284
  - EPSG:4178
- Standard transformation parameters

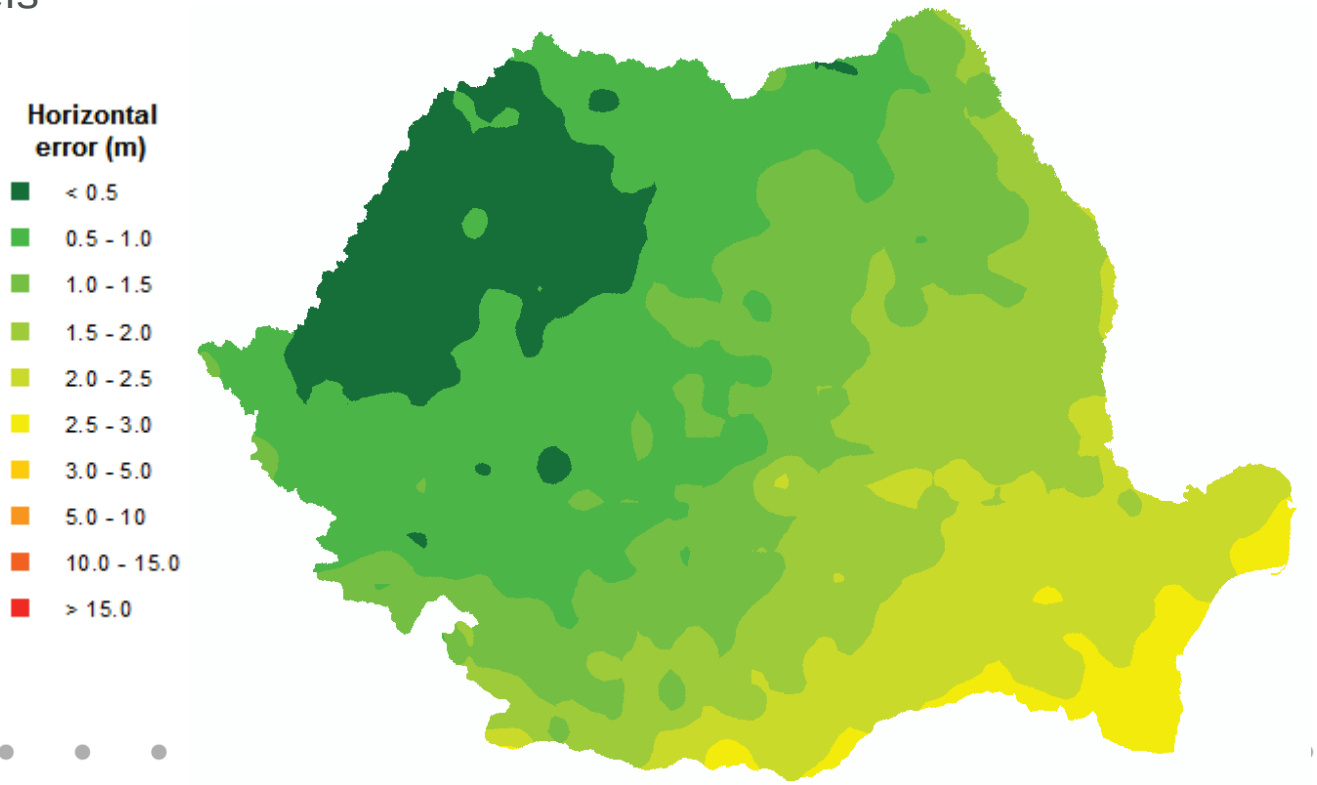
EPSG:31700 Dealul Piscului 1970 / Stereo 70

+proj=sterea +lat_0=46 +lon_0=25 +k=0.99975 +x_0=500000 +y_0=500000 +ellps=krass +towgs84=28,-121,-77,0,0,0,0 +units=m +no_defs



EPSG:3844 Pulkovo 1942(58) / Stereo70

+proj=sterea +lat_0=46 +lon_0=25 +k=0.99975 +x_0=500000 +y_0=500000 +ellps=krass +towgs84=33.4,-146.6,-76.3,-0.359,-0.053,0.844,-0.84 +units=m +no_defs



EPSG:4284 Pulkovo 1942 + Stereo70

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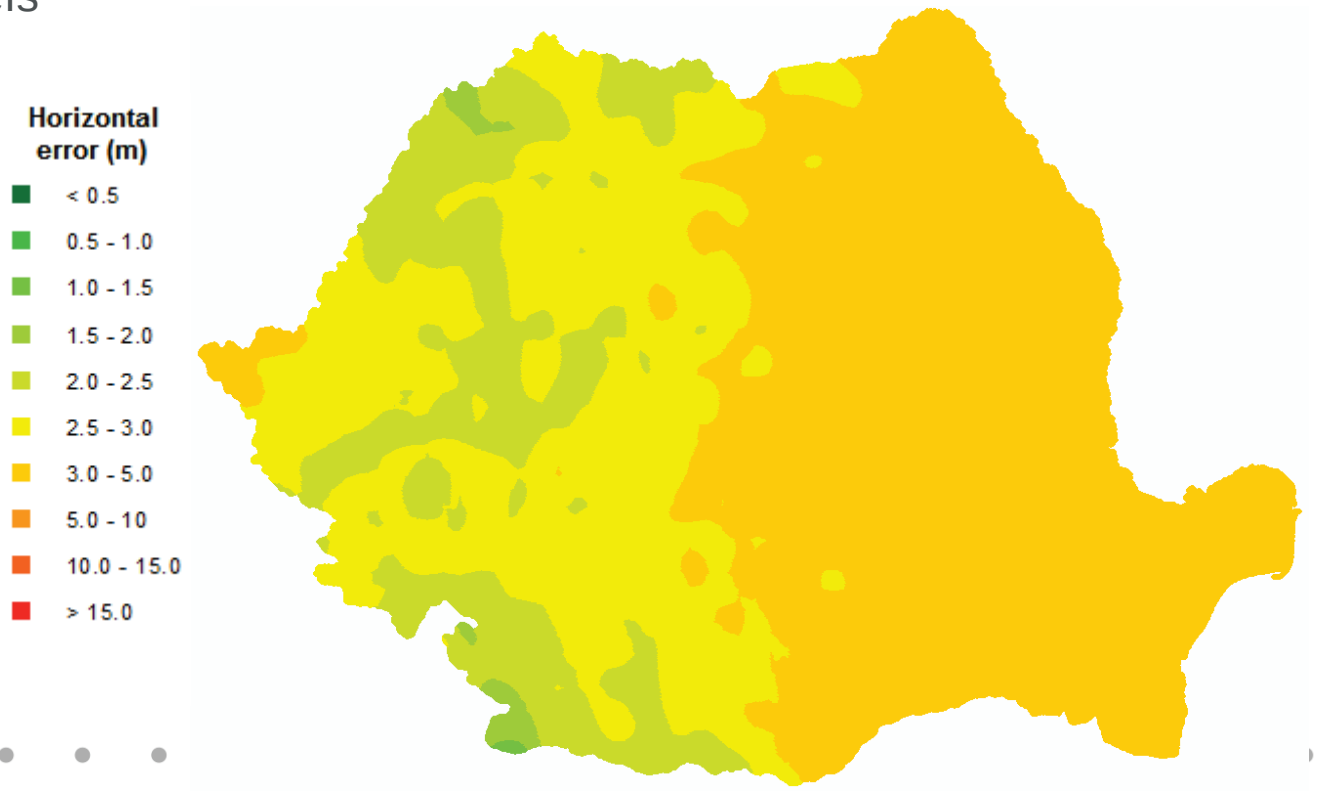
EPSG:4178 Pulkovo 1942(83) + Stereo70

+proj=sterea +lat_0=46 +lon_0=25 +k=0.99975 +x_0=500000 +y_0=500000 +ellps=krass +towgs84=33.4,-146.6,-76.3,-0.359,-0.053,0.844,-0.84 +units=m +no_defs



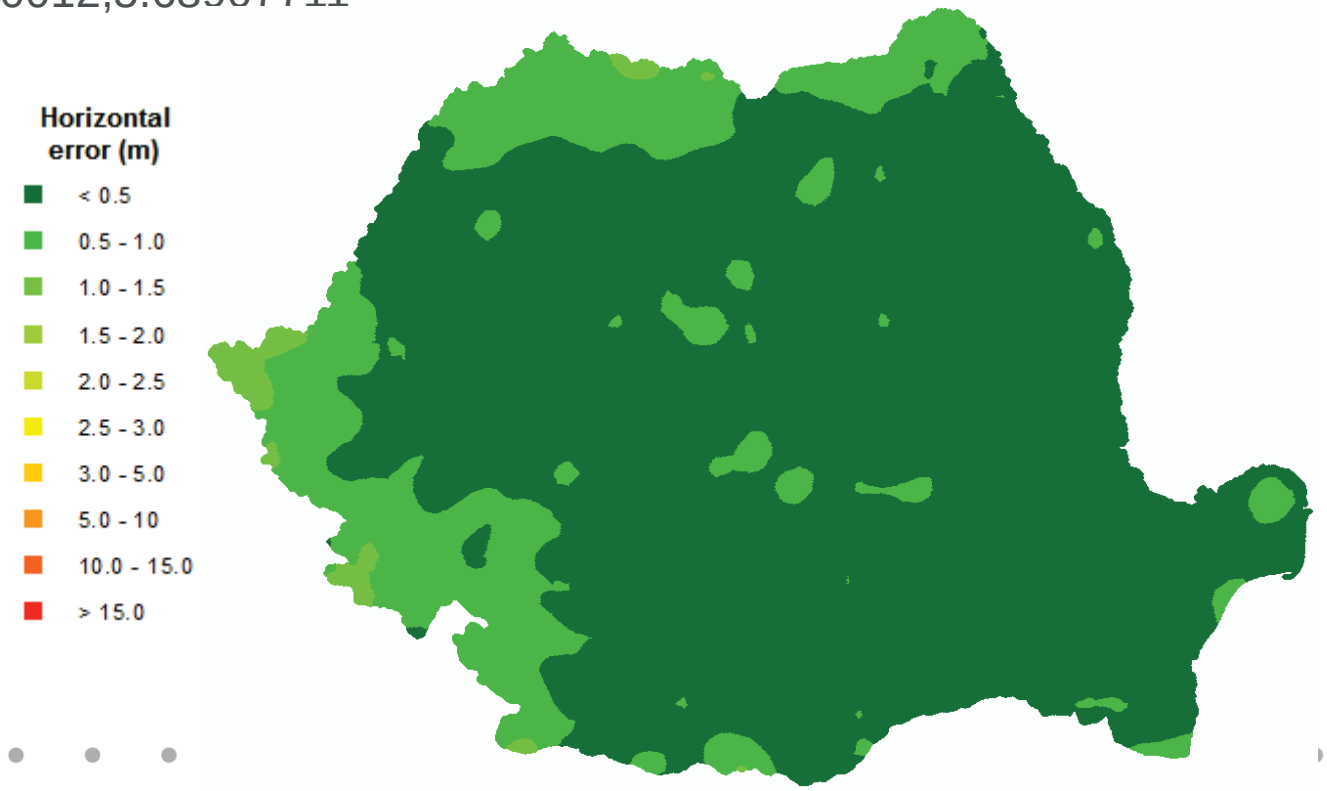
User-defined parameters

- Romanian Cadastre Agency:
  - 7-parameter “Helmert” transformation between “Sistem 42” and ETRS89

- Issues:
  - WGS84 and ETRS89 postulated identical (default PROJ4 behaviour)
  - “Wrong” sign for the rotation parameters (EPSG:9607 apparently used instead of the ISO 19111 recommended EPSG:9606, used by PROJ4)

User-defined parameters – ANCPI

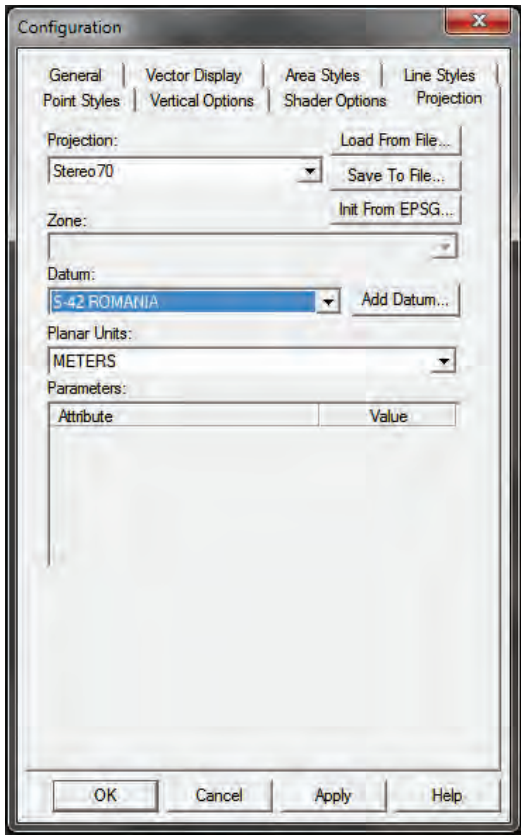
+proj=sterea +lat_0=46 +lon_0=25 +k=0.99975 +x_0=500000 +y_0=500000 +ellps=krass +towgs84=2.3283,-147.0416,-92.0802,-0.30924979,0.32482188, 0.49730012,5.68907711



4

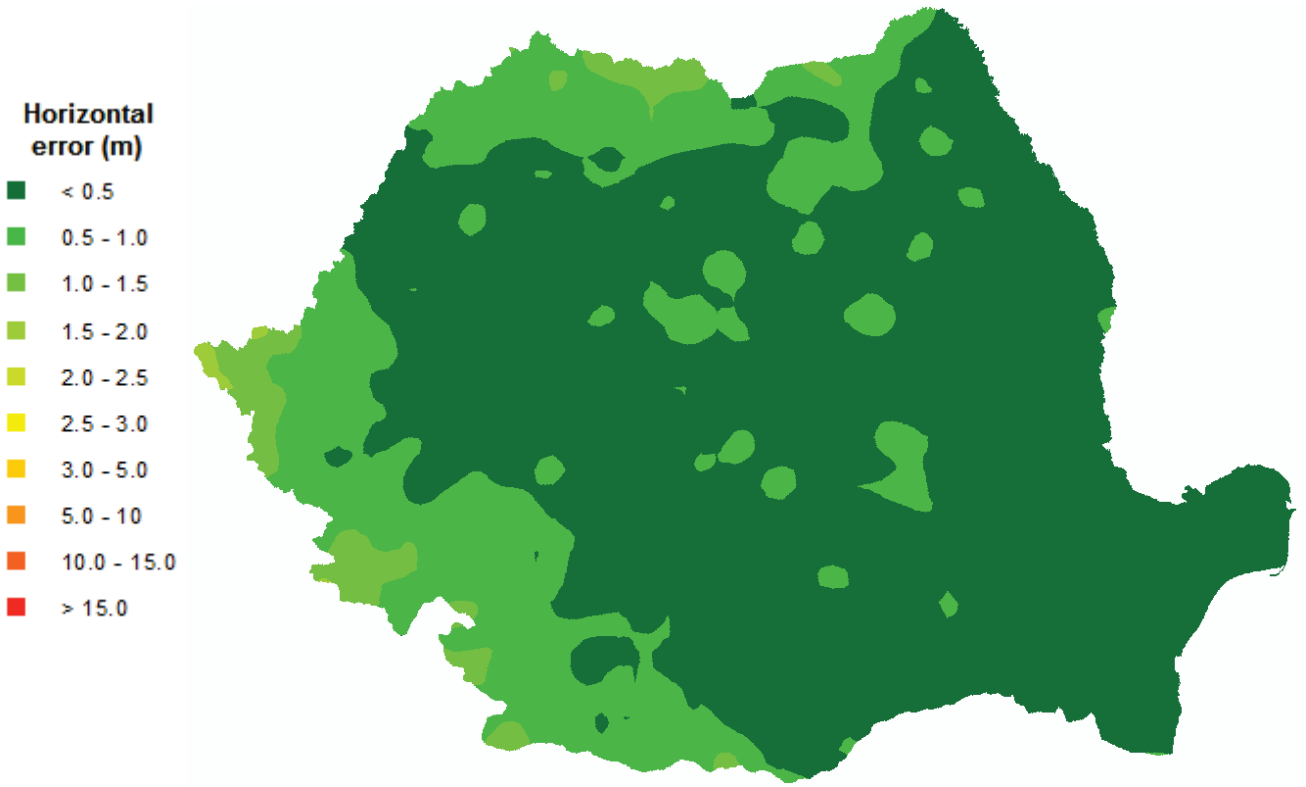
Alternative transformations: proprietary software

Global Mapper (v.14)

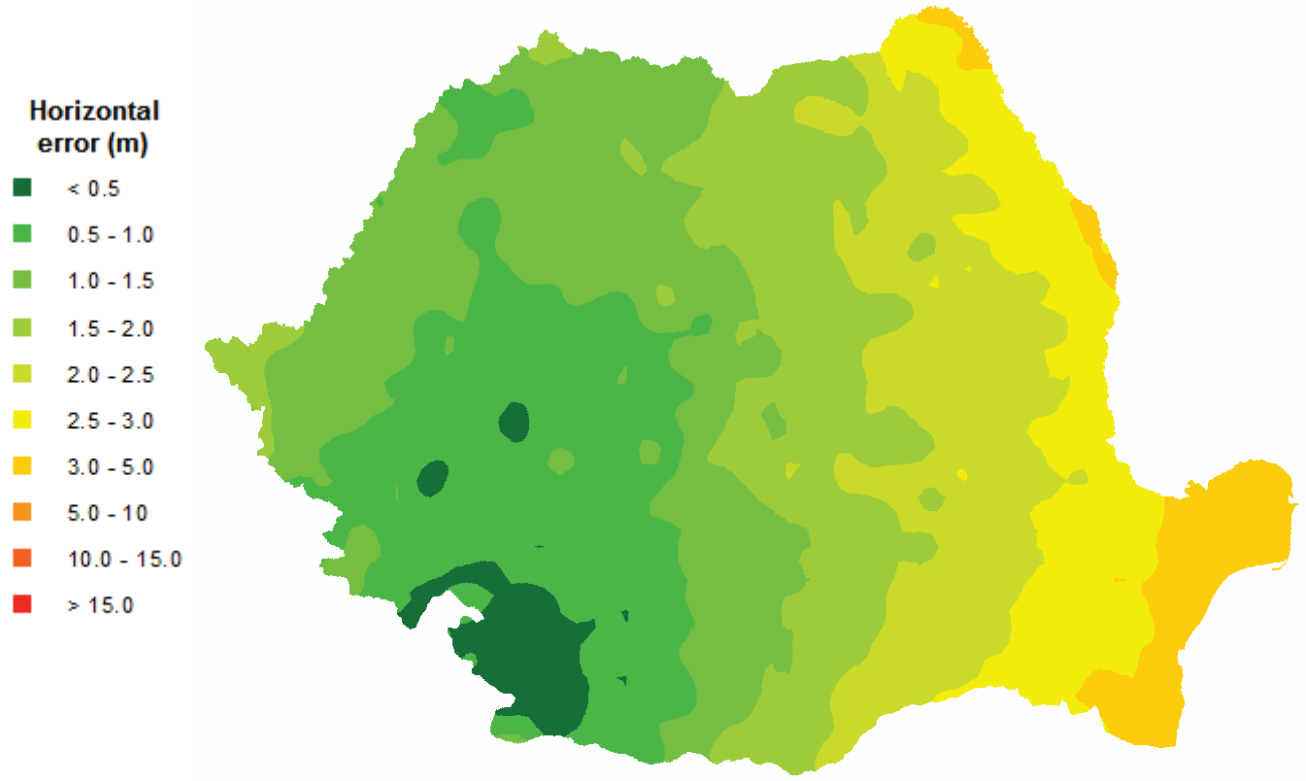


- Potentially applicable reference systems:
  - S-42 (Pulkovo 1942)
  - S-42 Romania
  - Dealul Piscului 1970

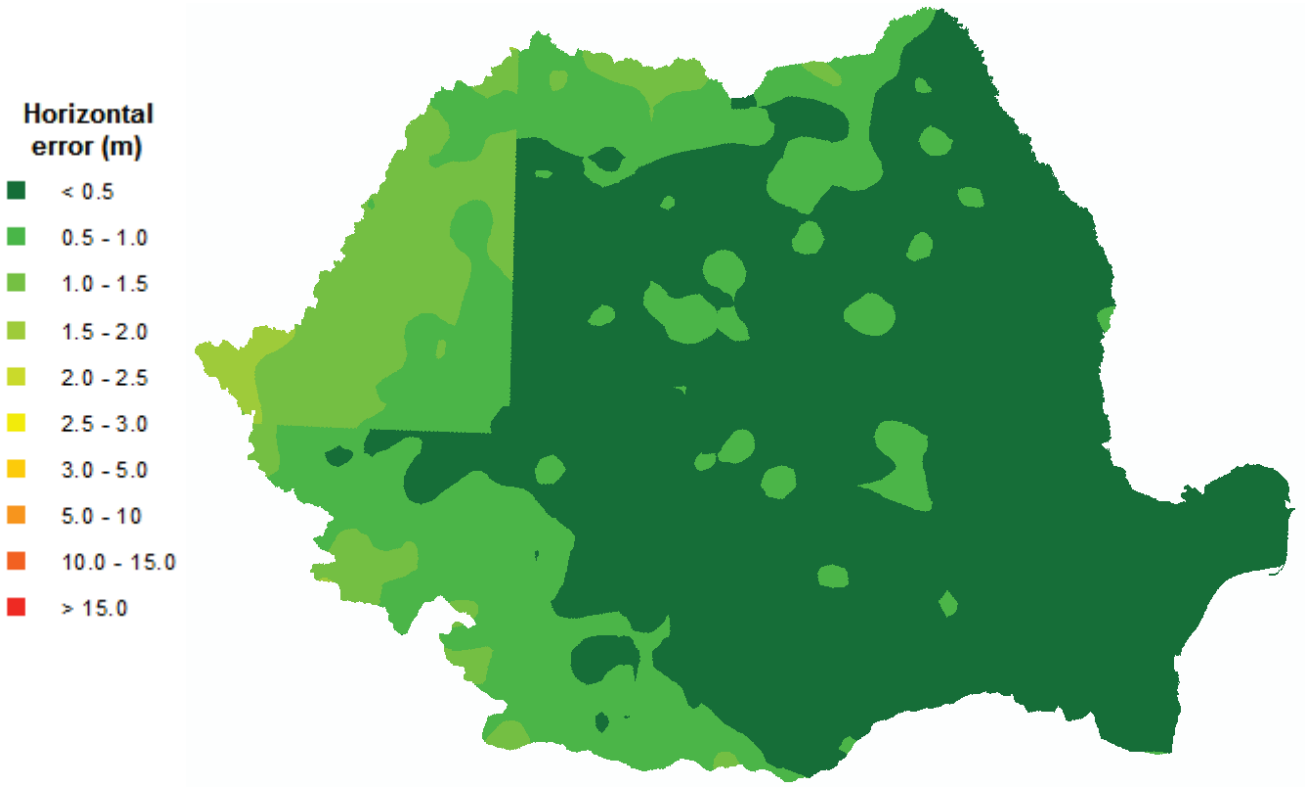
Stereo70 / S-42 Romania



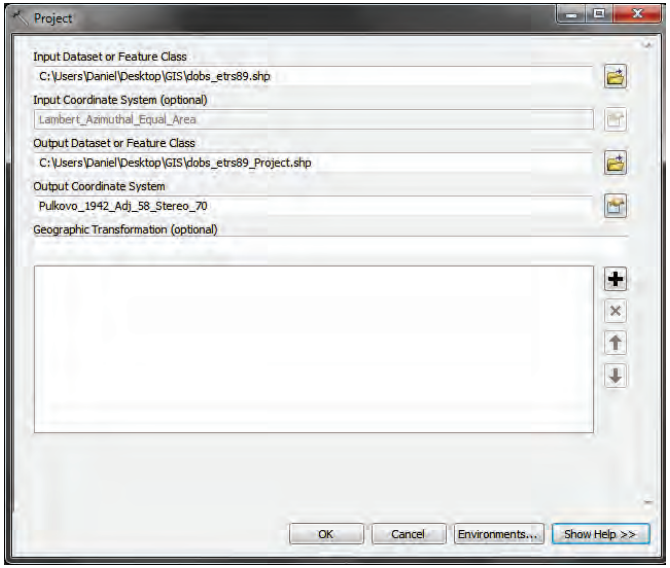
Stereo70 / Dealul Piscului 1970



Stereo70 / S-42 (Pulkovo 1942)

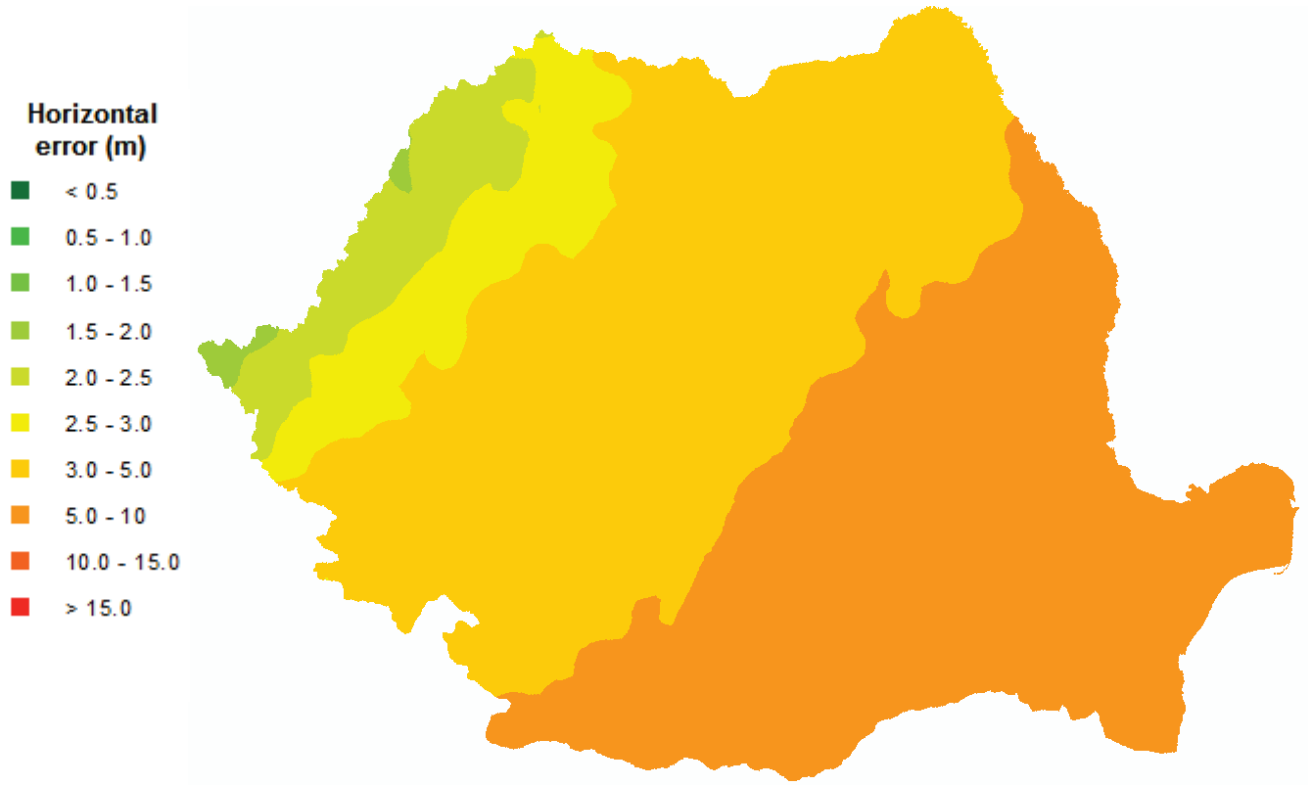


ESRI ArcGIS (v10.2)

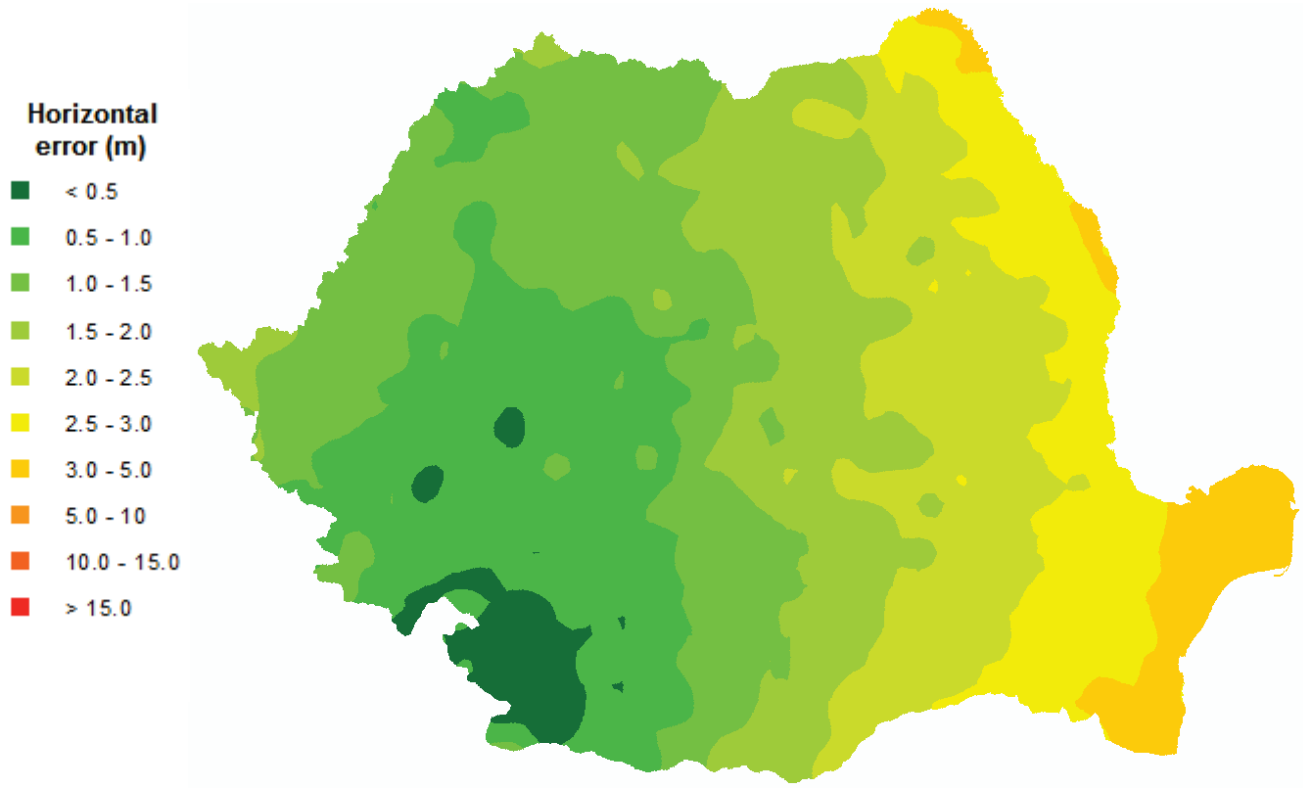


- Potentially applicable pre-defined transformations:
  - Dealul_Piscului_1970_to_WGS_1984_1
  - Dealul_Piscului_1970_to_WGS_1984_2
  - Pulkovo_1942_Adj_1958_To_ETRS_1989_4

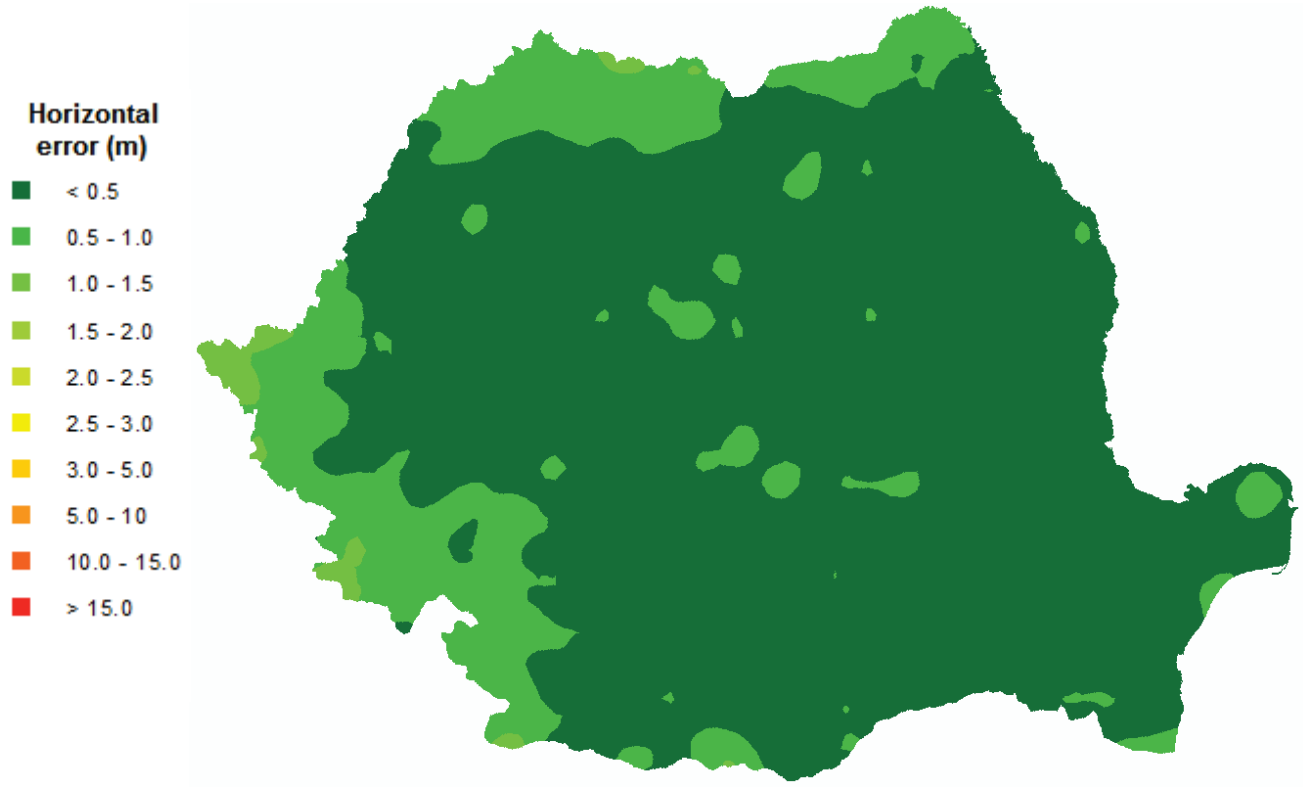
Dealul_Piscului_1970_to_WGS_1984_1



Dealul_Piscului_1970_to_WGS_1984_2



Pulkovo_1942_Adj_1958_To_ETRS_1989_4



5

Improving precision in FOSS

PROJ.4 – alternative algorithm

1. Convert ETRS89 ellipsoidal coordinated to rectangular coordinates in the oblique stereographic projection

2. Convert coordinates based on GRS80 ellipsoid to ones based on the Krasovski 1940 ellipsoid

3. Interpolate geometric corrections based on a grid of datum shifts

Grid shift files – NTV2

- Binary format developed in Canada and Australia
- *De facto* standard (official grid shift files published by Brazil, Germany, New Zealand, United States, South Africa, etc.)
- Used by PROJ4 for high precision transformations

Building a NTv2 file for Romania

- Issues:
  - NTv2 – grid points in geographical projection
  - ANCPI – grid points in stereographic projection

Building a NTv2 file for Romania

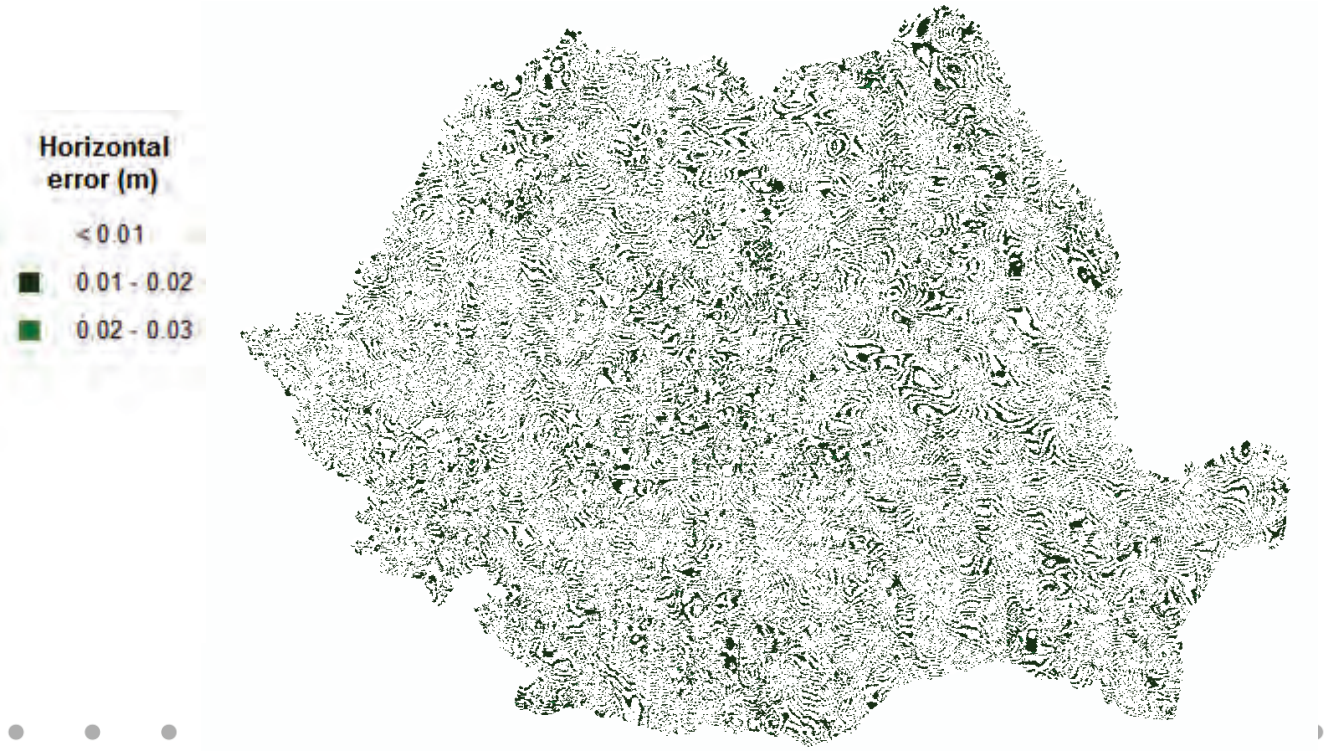
- Algorithm:
  - Generate a custom regular grid in geographical projection (35 sec latitude, 50 sec longitude) covering the territory of Romania
  - Convert grid to “Sistem 42” using TransDatRO
  - Convert back to WGS84 using PROJ4, ignoring datum transformations
  - Compute shifts between the points of the original grid and that of the reprojected one
  - Generate NTv2 binary file using the above shifts

https://github.com/danieluct/ntv2generator

(Work in progress)

Transformation using grid shifts file

+proj=sterea +lat_0=46 +lon_0=25 +k=0.99975 +x_0=500000 +y_0=500000 +ellps=krass +nadgrids=stereo70_etrs89A.gsb +units=m +no_defs



6

Conclusion

Comparing transformation accuracy

No	Transformation	Minimum error (m)	Maximum error (m)	Mean error (m)	Standard deviation (m)
1	PROJ.4 Generated grid shift file	0,000	0,029	0,007	0,003
2	PROJ.4 ANCPI parameters + Stereo70	0,000	1,463	0,339	0,219
3	ArcGIS 10.2 Pulkovo_1942_Adj_1958_To_ETRS_1989_4	0,000	1,464	0,339	0,219
4	Global Mapper 14.0 Stereo70 / S-42 Romania	0,000	1,718	0,416	0,250
5	Global Mapper 14.0 Stereo70 / S-42 (Pulkovo 1942)	0,000	1,949	0,488	0,325
6	PROJ.4 EPSG:3844 Pulkovo 1942(58) / Stereo70	0,001	2,976	1,290	0,647

Comparing transformation accuracy

No	Transformation	Minimum error (m)	Maximum error (m)	Mean error (m)	Standard deviation (m)
7	ArcGIS 10.2 Dealul_Piscului_1970_to_WGS_1984_2	0,004	3,587	1,640	0,774
8	Global Mapper 14.0 Stereo70 / Dealul Piscului 1970	0,001	3,593	1,650	0,776
9	PROJ.4 EPSG:31700 Dealul Piscului 1970 / Stereo 70	0,004	3,587	1,648	0,774
10	PROJ.4 EPSG:4178 Pulkovo 1942(83) + Stereo70	1,195	4,918	3,124	0,619
11	ArcGIS 10.2 Dealul_Piscului_1970_to_WGS_1984_1	1,690	8,312	4,698	1,495
12	PROJ.4 EPSG:4284 Pulkovo 1942 + Stereo70	3,731	7,304	5,686	0,498

Further work

- Modify EPSG:3844 to use parameters published by the Romanian Cadastre Agency
- Official endorsement of the NTv2 grid shift file / Publication of a ANCPI-generated grid shift file based on latest measurements
- OGR/GDAL support for vertical grid shift files

7

Questions?

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Thank you!