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Experience from implementation of the new national CRS realisation in Slovakia

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Moldova

Agenda

- Legal introduction of the new national CRS realization JTSK03 in Slovakia
- JTSK03
  - History
  - Definition
  - JTSK03 relation to ETRS89
- Problems occurred during JTSK03 implementation
- Conclusions and recommendations

§ Legislation §

- 1st April 2011 – **JTSK03** as a new realisation (new reference frame) of the national CRS (S-JTSK) in Slovakia was introduced
- **JTSK03** validation was introduced by acceptance of Amendment 75/2011 Z.z. of UGKK SR Regulation 300/2009 Z.z.
- Amendment 75/2011 Z.z. says:
  - "… actual reference frame of national coordinate reference system S-JTSK is realisation JTSK03."
  - "… Valid JTSKyy realisation has defined relation to national ETRS89 realisation which was computed from and has a homogenous scale with it."

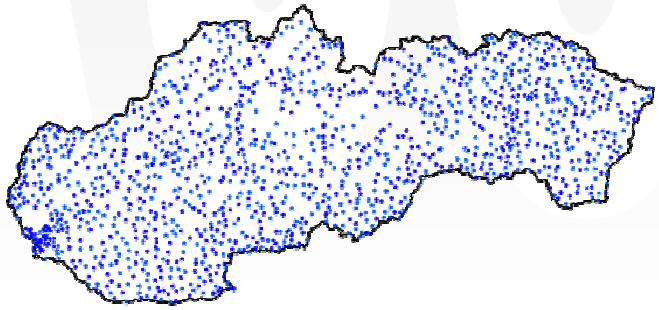
What is JTSK03?

JTSK03

New reference frame of national CRS S-JTSK ✓

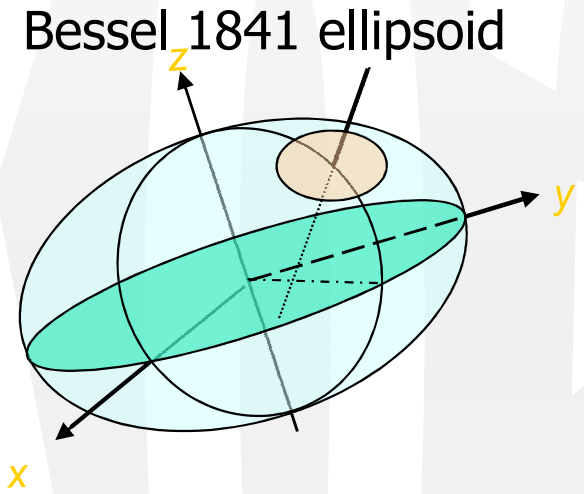
- new realisation of old national CRS S-JTSK
- planar 2D system
- JTSK03 is based on relation to ETRS89
- all points which have coordinates determined in ETRS89 have also coordinates in JTSK03 and this is valid vice verse

New national CRS ✗

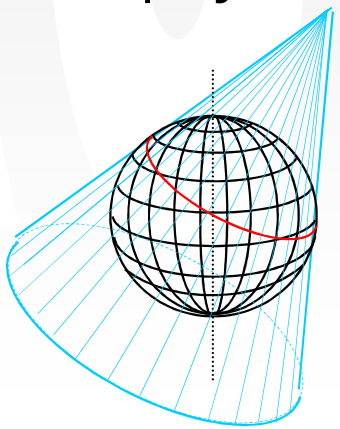


S-JTSK
national CRS in Slovakia

- S-JTSK stands for: System of unified trigonometric cadastre network
- 2D CRS
- Defined in cca. 1919-1920 year
- <u>Definition:</u>
  - Bessel 1841 ellipsoid
  - Krovak projection – oblique conformal conic projection



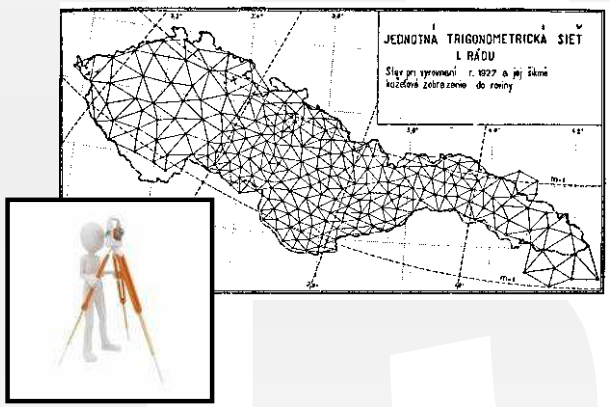
Křovák projection



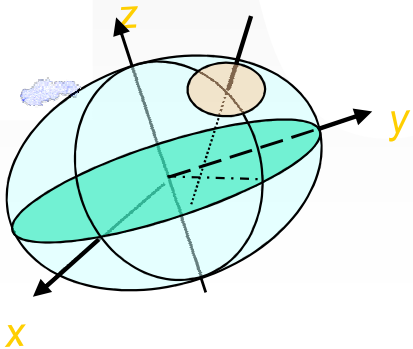
S-JTSK realisations

Former JTSK realisation

- Precise angular measurements in Trigonometric network

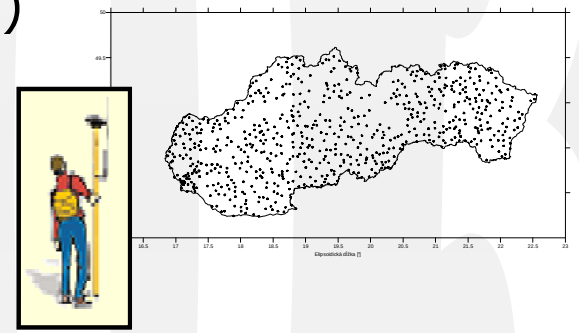


- Adjusted network - fixed to Bessel 1841 ellipsoid through astronomical points + baseline measurement

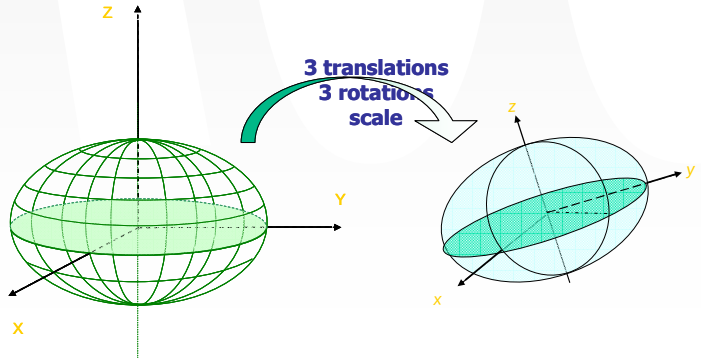


New JTSK03 realisation

- Precise GNSS measurements in National spatial network (ETRS89 – ETRF2000)



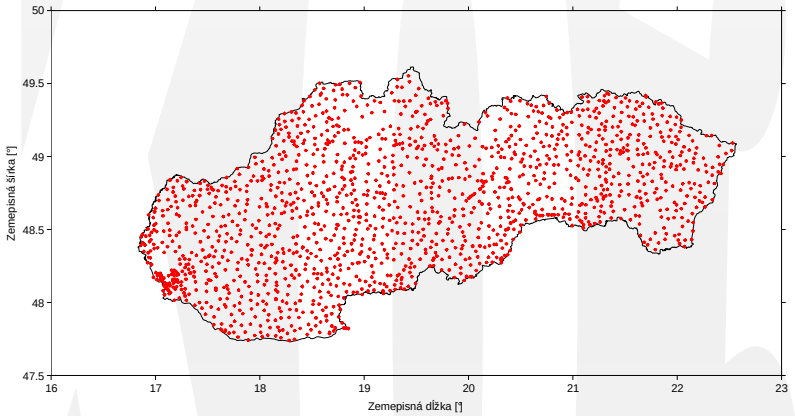
- Adjusted coordinates (network) - fixed to Bessel 1841 ellipsoid from GRS80 ellipsoid through 7 Helmert parameters



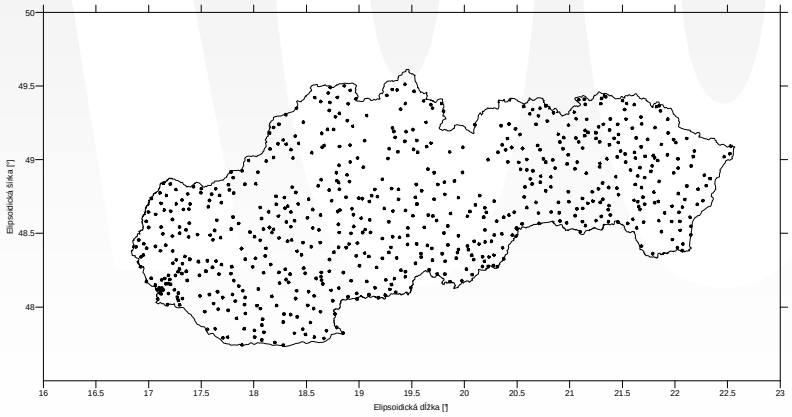
Relation between S-JTSK (JTSK03) and ETRS89 (ETRF2000)

- ETRS89 is represented in Slovakia by National spatial network (ŠPS) in SKTRFyyyy (Slovakian terrestrial reference frame)
- actual version is SKTRF2009 = ETRF2000
  - based on permanent measurements
- All points from National Spatial network (ŠPS) have ETRS89 coordinates
- 50% of ŠPS C - class have also former JTSK coordinates

National spatial network (ŠPS) – C class



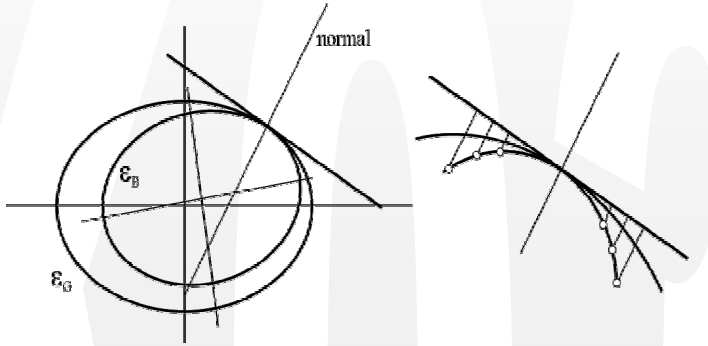
ŠPS points with former JTSK coordinates



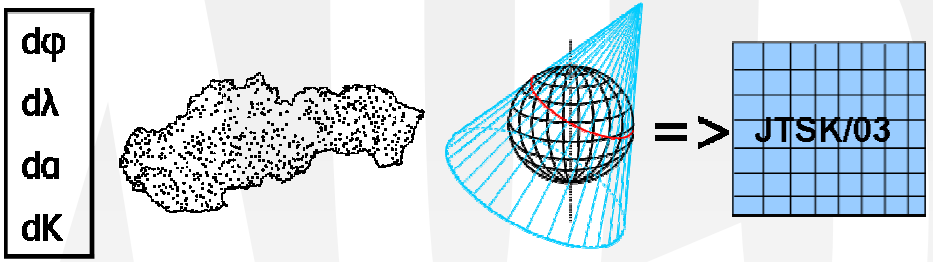
Determination of relation between ETRS89 and S-JTSK

- 3 step process:

1. Estimation of 4 transformation parameters – Transformation on ellipsoid surface with coincides normals

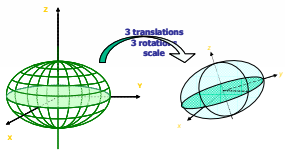


2. Computation of JTSK03 coordinates (usage of 4 transformation parameters)



3. Estimation of 7 Helmert parameters (3D Helmert transformation) between ETRS89 coordinates and JTSK03 coordinates determined from 4 transformation parameters estimation = estimation GRS80 ↔ Bessel 1841 relation

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}^B = \begin{bmatrix} c_x \\ c_y \\ c_z \end{bmatrix} + (1 + s \times 10^{-6}) \cdot \begin{bmatrix} 1 & -r_z & r_y \\ r_z & 1 & -r_x \\ -r_y & r_x & 1 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}^A$$



JTSK03 implementation to law

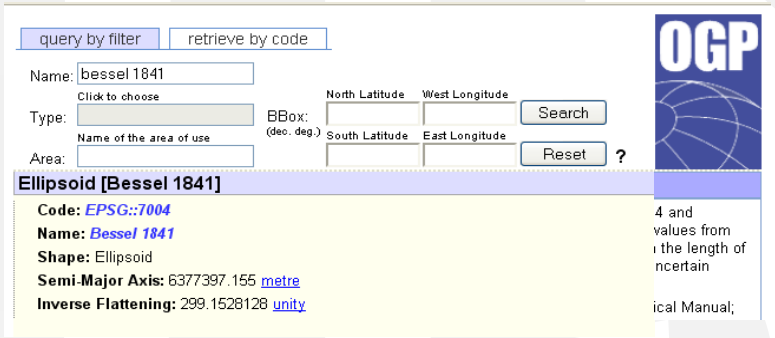
- For legal usage it is important to implement the new realisation to legislative

- First of all for that step you need unique definition about all JTSK03 parts and about procedure of coordinate determination
  - Definition of used ellipsoids
  - Definition of used projection
  - Definition of type and parameters of transformation
  - …

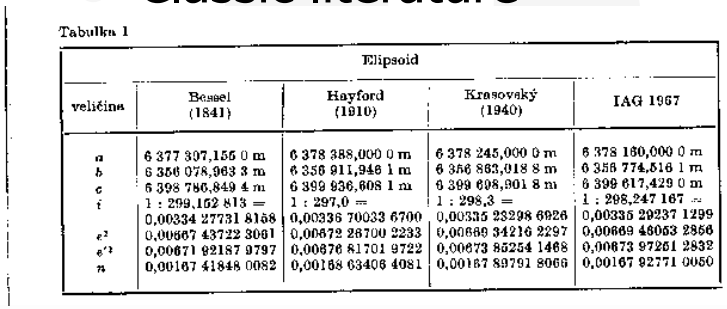
- Sometimes few problems (usually formal) occur during the process of implementation
- In Slovakia there are:
  - "formal" problem with correct definition of Bessel 1841 ellipsoid,
  - Definition of Helmert transformation reversibility

Problem with Bessel 1841 ellipsoid correct definition

- different types of Bessel 1841 ellipsoid parameters



Classic literature



Tabulka 1

veličina	Elipsoid Bessel (1841)	Hayford (1910)	Krasovský (1940)	IAG 1967
a	6 377 397,155 0 m	6 378 388,000 0 m	6 378 245,000 0 m	6 378 160,000 0 m
b	6 356 078,963 3 m	6 356 911,946 1 m	6 356 863,018 8 m	6 356 774,516 1 m
c	6 398 786,849 4 m	6 399 936,608 1 m	6 399 698,901 8 m	6 399 617,429 0 m
i	1 : 299,152 813 =	1 : 297,0 =	1 : 298,3 =	1 : 298,247 167 =
	0,00334 27731 8158	0,00336 70033 6700	0,00335 23298 6926	0,00335 29237 1299
e^2	0,00667 43722 3061	0,00672 26700 2233	0,00669 34216 2297	0,00669 45063 2856
e'^2	0,00671 92187 9797	0,00676 81701 9722	0,00673 85254 1468	0,00673 97261 2832
n	0,00167 41848 0082	0,00168 63406 4081	0,00167 89791 8066	0,00167 92771 0050

Which parameters are correct?
Why are they different?

Maybe because in the past, parameters were computed with usage of logarithmic tables – problem with decimals numbers

Reversibility of Helmert 7-parameter transformation

- Mathematic formula:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}^{TARGET} = \begin{pmatrix} T_X \\ T_Y \\ T_Z \end{pmatrix} + \left(1 + s \cdot 10^{-6}\right) \cdot \begin{pmatrix} 1 & -R_Z & R_Y \\ R_Z & 1 & -R_X \\ -R_Y & R_X & 1 \end{pmatrix} \cdot \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}^{SOURCE}$$

- Inversion (reverse equation)
  - pure mathematic

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}^{SOURCE} = \left(1 + s \cdot 10^{-6}\right)^{-1} \cdot \begin{pmatrix} 1 & -R_Z & R_Y \\ R_Z & 1 & -R_X \\ -R_Y & R_X & 1 \end{pmatrix}^{-1} \cdot \left[\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}^{TARGET} - \begin{pmatrix} T_X \\ T_Y \\ T_Z \end{pmatrix} \right]$$

  - In literature

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}^{SOURCE} = \begin{pmatrix} -T_X \\ -T_Y \\ -T_Z \end{pmatrix} + \left(1 - s \cdot 10^{-6}\right) \cdot \begin{pmatrix} 1 & -R_Z & R_Y \\ R_Z & 1 & -R_X \\ -R_Y & R_X & 1 \end{pmatrix}^{T} \cdot \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}^{TARGET}$$

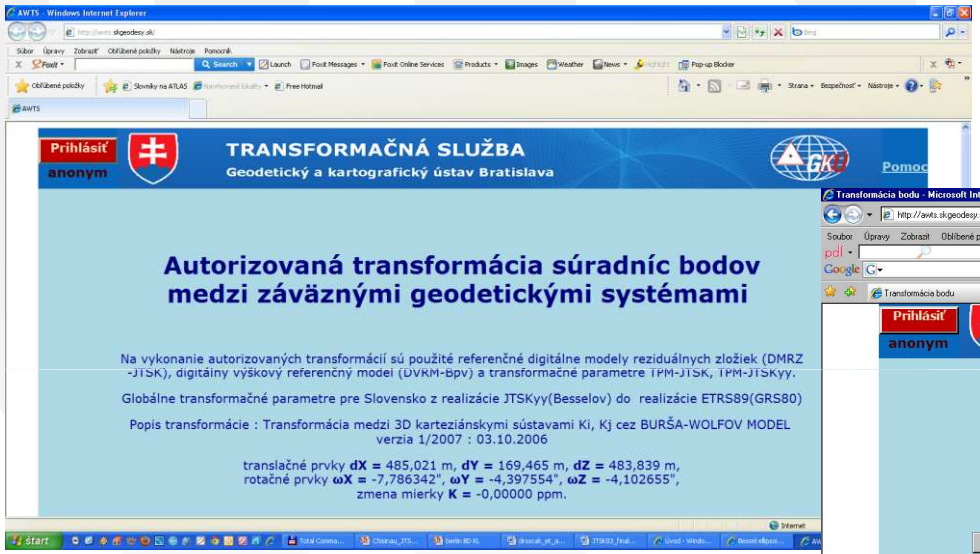
  - In software? Nobody knows

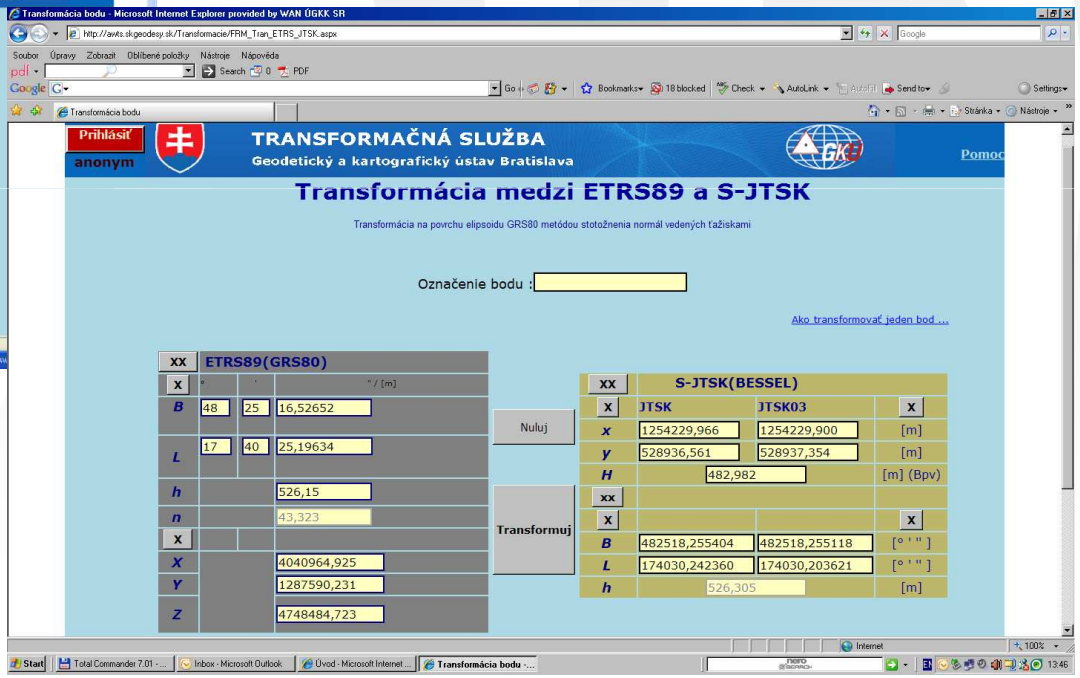
Reversibility of Helmert 7-parameter transformation

- Possible Solutions for reversibility problem
  - Estimation of 2 set of parameters (mathematically not pure)
    - From target to source
    - From source to target
  - 1 set of parameters + mathematic inversion
    - Only few software can apply
  - 1 set of parameters – without inverse possibility
    - All software can apply

Reversibility of Helmert 7-parameter transformation - Solution in Slovakia

- 1 set of parameters + Web Reference transformation service = AWTS application (Authorized Web Transformation Service)

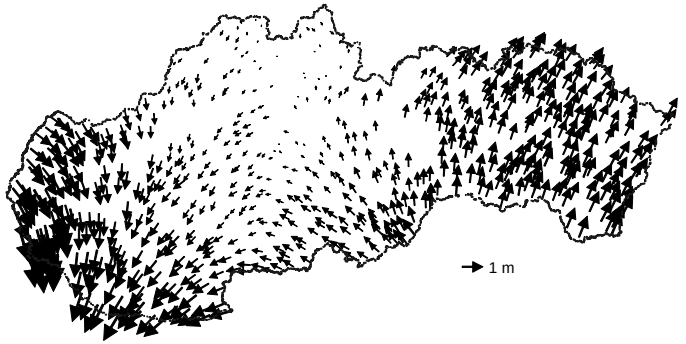


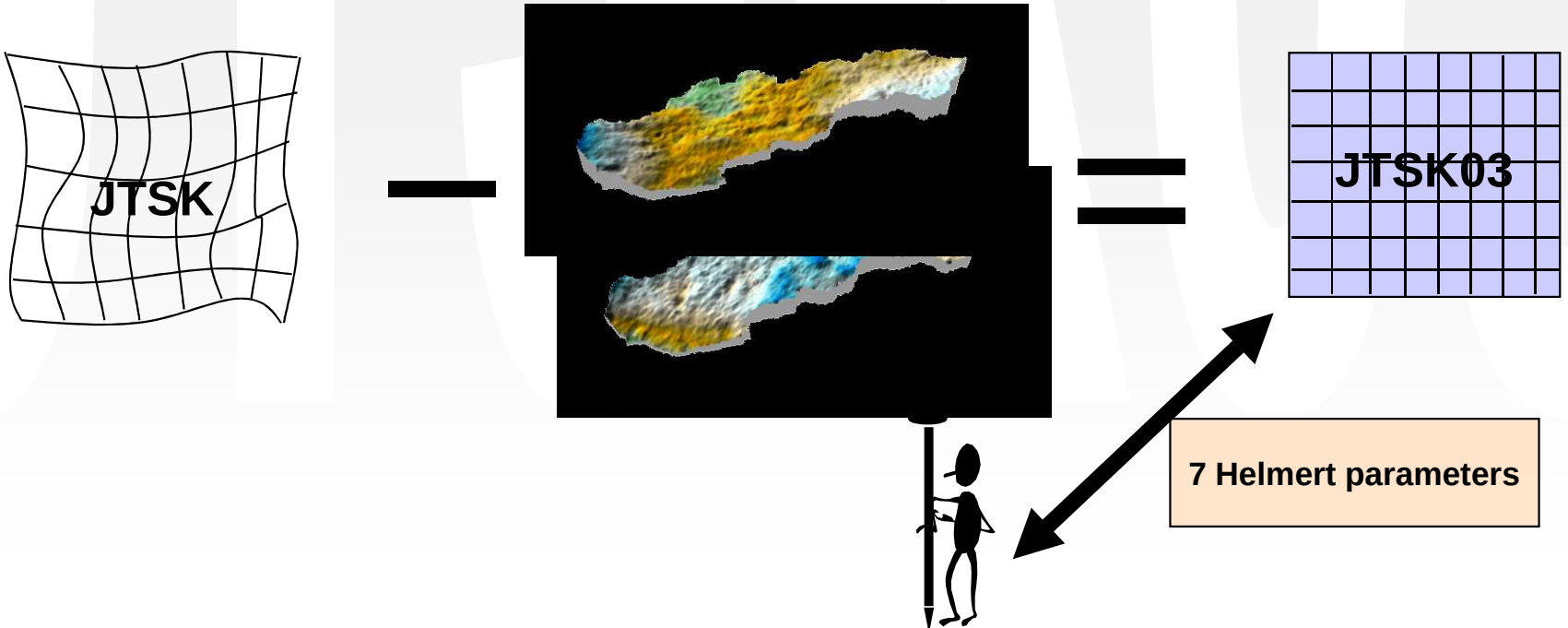


http://awts.skgeodesy.sk

Relation between JTSK and JTSK03

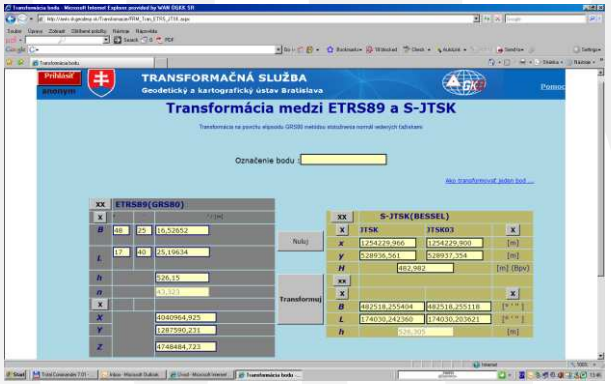
- Distortions models computed from identical points
- Distortions up to 1.3m
- Separate models for both axes (x,y)
- Grid creation – krigging





Relation between JTSK and JTSK03

- Possibilities of JTSK – JTSK03 conversion
  - Usage of distorsion models
    - Available on AWTS
    - Average global quality – 4cm
      - Sufficient for lot of applications



  - Usage of local transformations
    - Computation of own local transformation parameters

Recent dilemma in Slovakia

- Reversibility of Helmert transformation
- Hamlet question: Introduced or not introduced the reverse set of 7 Helmert parameters, this is a question?
- Pros
  - Lot of users will be able to get correct JTSK03 or ETRS89 values by their own software not only if they use AWTS
- Cons:
  - 2 set of parameters are not mathematically pure solution

Conclusion

- Presented example shows that it is not problem to determine the new realisation of any old CRS, but how you can see it is the problem correctly and uniformly to define its relation to nowadays used and recommended systems like ETRS89
- So our recommendation is that if you decide to introduce new set of coordinates for national CRS it will be better to define totally new system not only new frame of old system
- You will avoid complications like it was mentioned in slides above

Thank you for your attention

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