Further Developments and Testing of DFHRS (DFHBF-Software) and its Extension for Physical Observations

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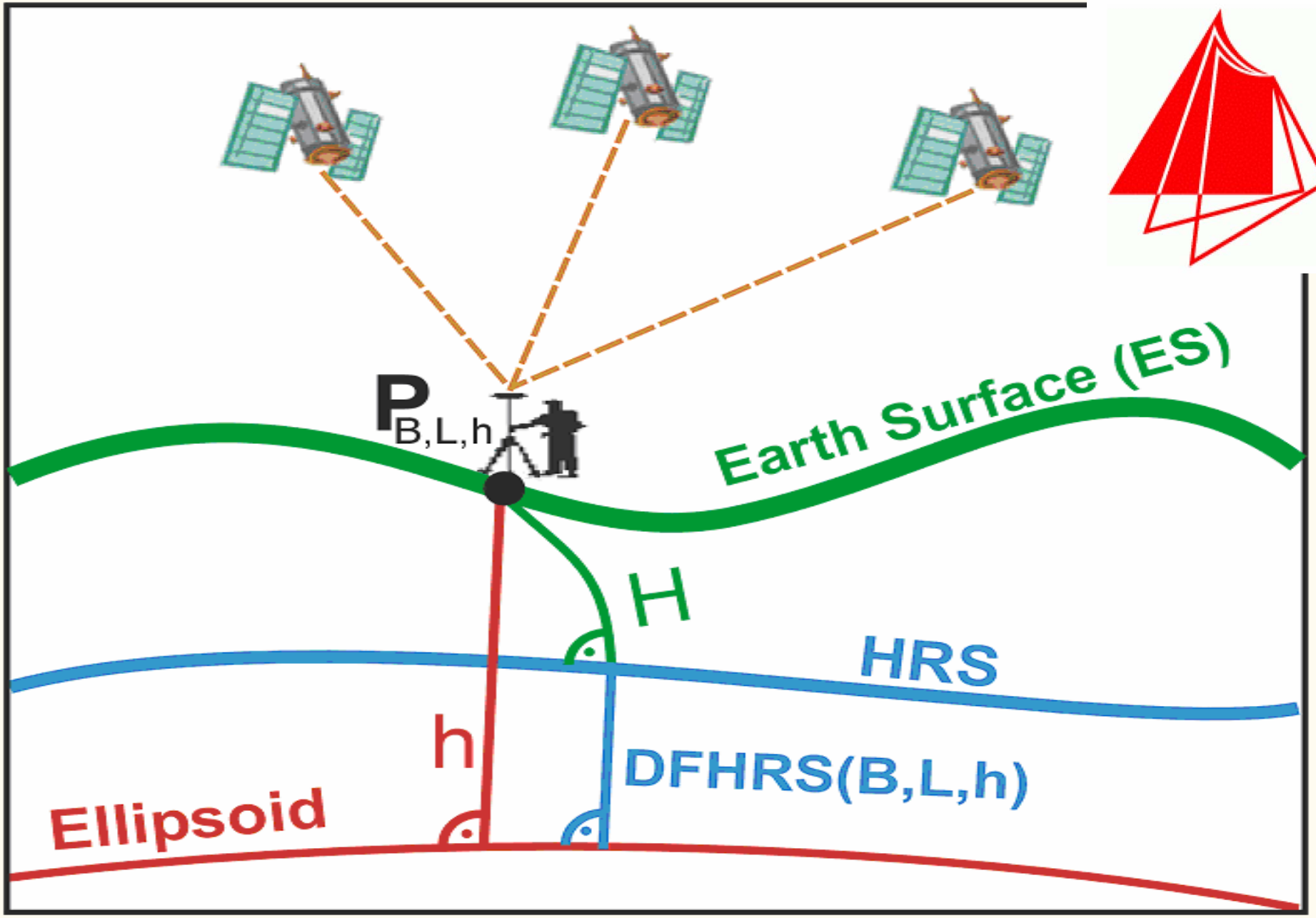
DFHRS (DFHBF-Software)

- Digital Finite-Element Height Reference Surface => DFHRS
- Digitale Finite-Element Höhen- Bezugs-Fläche => DFHBF.

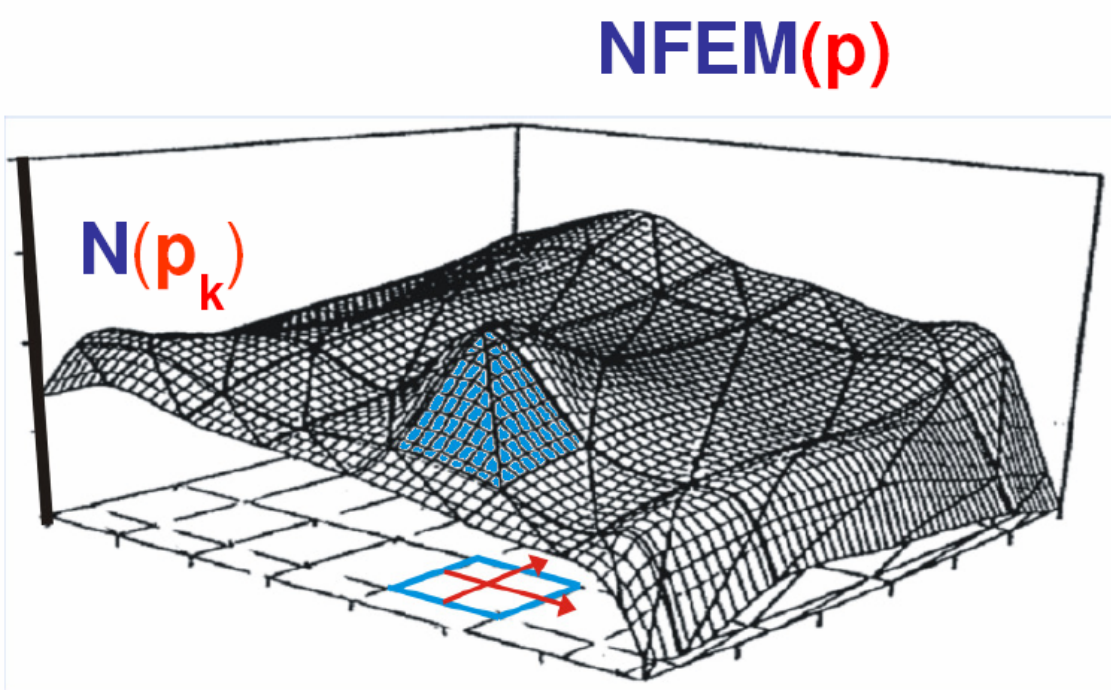
  www.dfhbf.de

  www.geozilla.de
- Target : To calculate a reference system for GNSS/GPS measurement to enable GPS-Height integration


P B,L,h
Earth Surface (ES)
H
HRS
h
DFHRS(B,L,h)
Ellipsoid

DFHBF-Idea 1/2

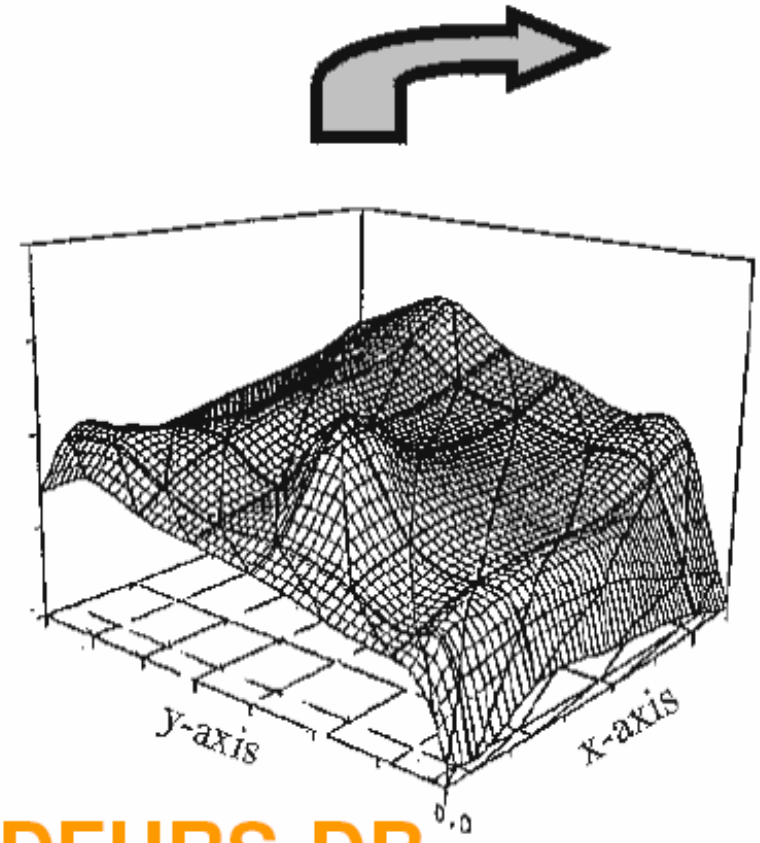
- An area is divided to smaller finite elements called meshes.
- The height reference surface is calculated for each element (mesh) as a polynolial.
- Continuity condition between all elements is considered to have a continuous surface.
- The calculated parameters are stored in a database : DFHBF_DB.

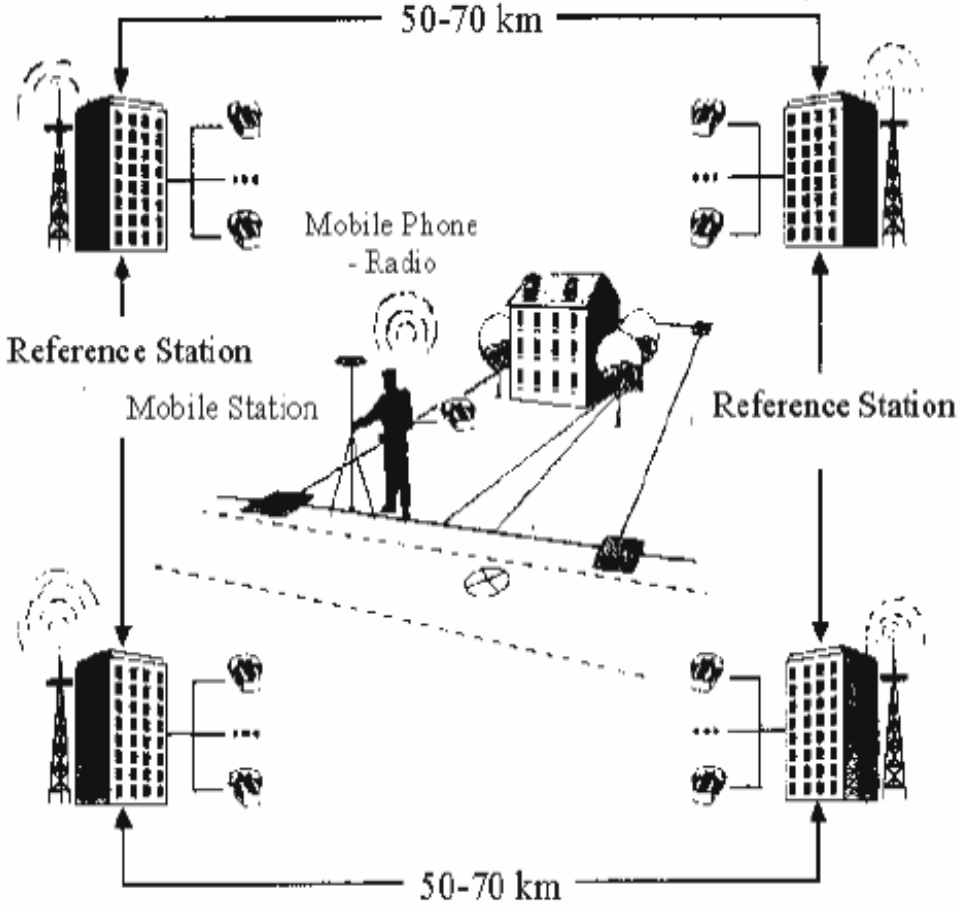


DFHBF

DFHBF-Idea 2/2

- DFHBF_DB is provided to GPS/GNSS-serivces Companies, e.g SAPOS in Germany.
- DFHBF_DB in GNSS controller (Reciever) direct Access via DLL (Topcon & Trimble)or access by a Grid (Leica & Trimble).
- Future: The GPS/GNSS-serivces Company send back the corrections including the Height correction from DFHBF_DB. (RTCM 3.1 Transformation messages).





DFHRS-DB

DFHBF

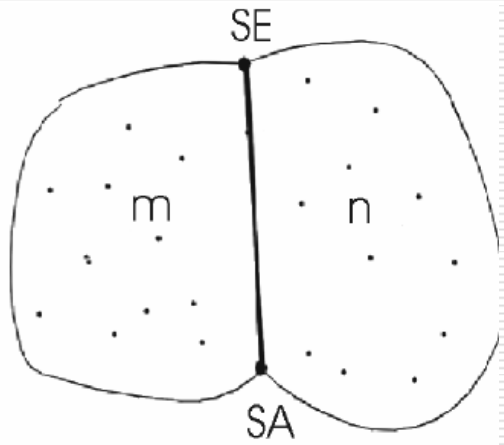
DFHBF-Concept 1/2

- the height reference system NN in a mesh is calculated by a polynomial in term of xy-coordinates. With Design matrix **F**, and Parameters matrix **P**

$$N(\mathbf{p}_k) = \sum_{i=0}^{l} \sum_{j=0}^{l-i} a_{ij,k} \cdot y^i x^j = \mathbf{f}^T \cdot \mathbf{p}_k$$

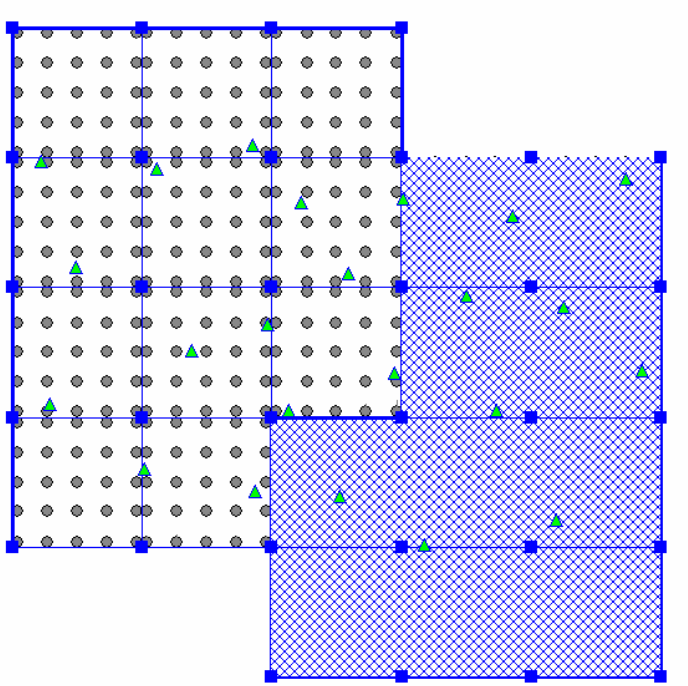
- The surface between two neighbouring meshes should continuous. with C0, C1, C2 continuity levels at the border line

$$N_{FEM} = \left\{ \begin{array}{c} N(\mathbf{p}_k) = \sum_{i=0}^{l} \sum_{j=0}^{l-i} a_{ij,k} \cdot y^i x^j = \mathbf{f}^T \cdot \mathbf{p}_k \\ \\ C_{0,1,2}(\mathbf{p}_m ; \mathbf{p}_n) \end{array} \right\}$$



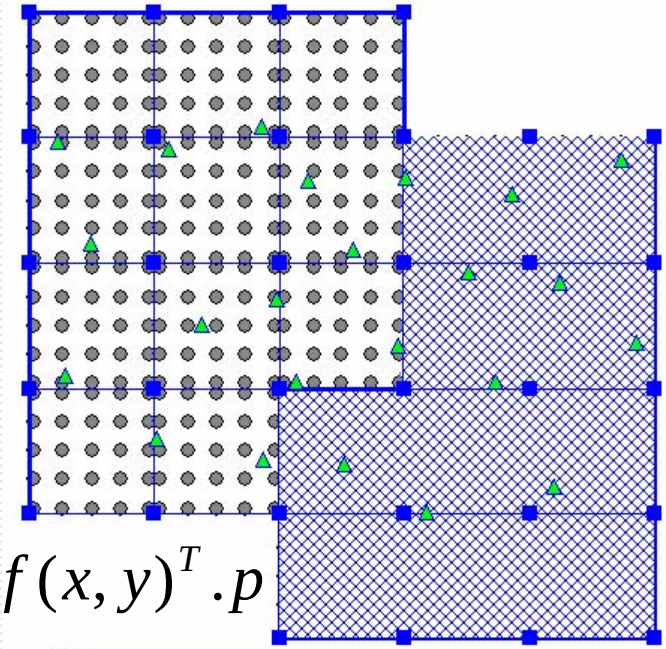
DFHBF-Concept 2/2

- Each group of meshes form a Patch.
- This allows applying datum corrections for different groups of observations.

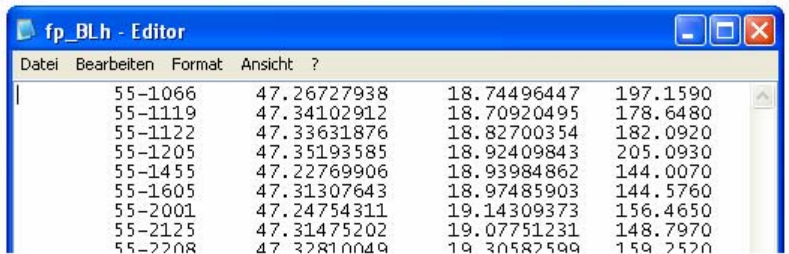


DFHBF- Input 1 / fixed points

- Points with known Heights in both GPS-height and land height system (Orthometric / Ortho-Normal)



$$h + v = H + h.\Delta m + f(x,y)^T.p$$



DFHBF- Input 2 /Global Potenial Models

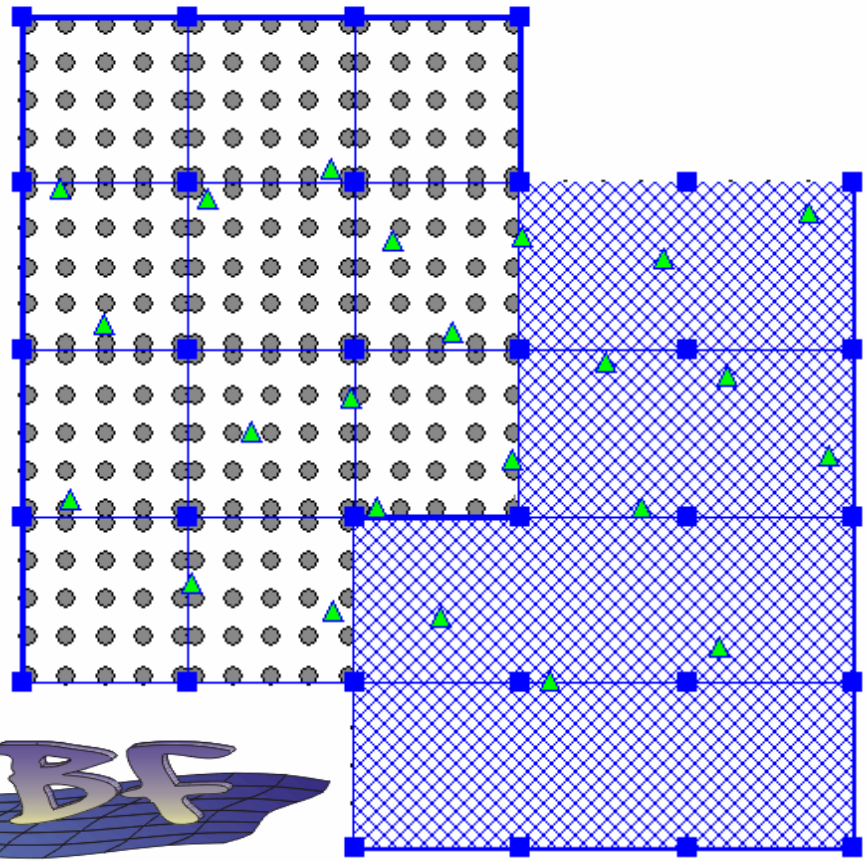
- In Global Potential Models -GPM are applied :EGM96 - Global, EGG97 –europe , Eigen05c.
- The Geoid Undolations:

$$N_{GPM} + v = f(x,y)^T . p + \partial N(d^j)$$

- The Deflections of Vertical:

$$\xi^j + v = \frac{-f_B^T}{M(\phi)} . p + \partial \xi(d^j_{\eta,\xi})$$

$$\eta^j + v = \frac{-f_L^T}{N(\phi).\cos(\phi)} . p + \partial \eta(d^j_{\eta,\xi})$$



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DFHBF- Input 3 / Astronomical Obs.

- The deflections of vertical from astronmical calculations or Zenith-Cameras can be applied.

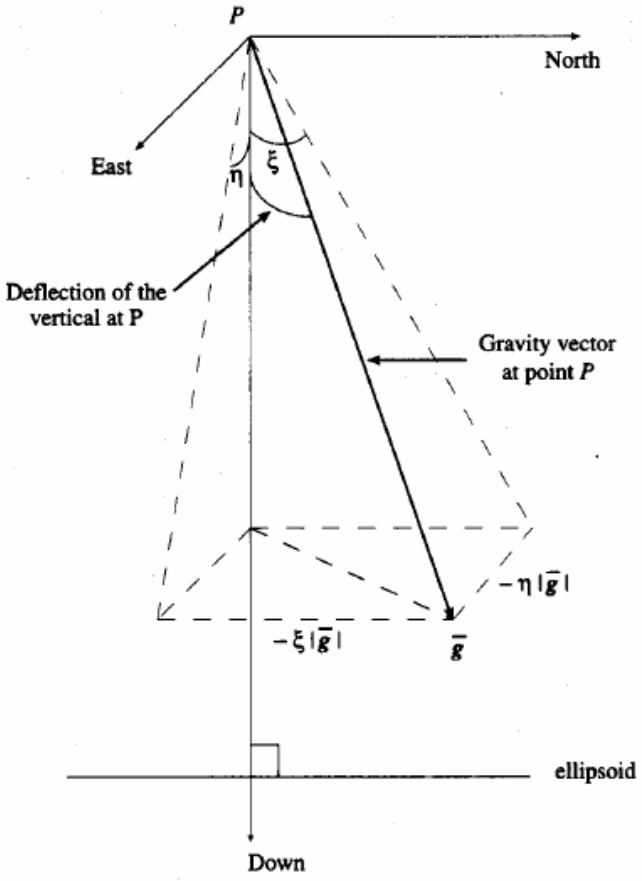
$$\xi^j + v = \frac{-f_B^T}{M(\phi)}.p + \partial\xi(d^j_{\eta,\xi})$$

$$\eta^j + v = \frac{-f_L^T}{N(\phi).\cos(\phi)}.p + \partial\eta(d^j_{\eta,\xi})$$

DFHBF

DFHBF- Input 4/ Physical Obs.

- the measured gravity data can be applied to DFHBF using Local representation methods:



$$\begin{bmatrix} g_x \\ g_y \\ g_z \end{bmatrix}^{ECF} = R(B, L, \eta, \xi)^{ECF}_{LAV} \cdot \begin{bmatrix} 0 \\ 0 \\ -g \end{bmatrix}^{LAV}$$

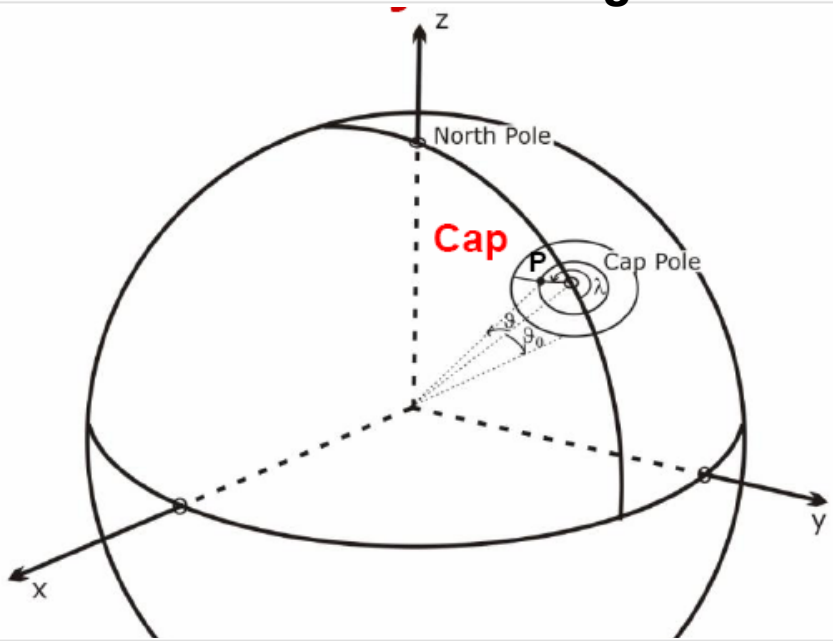
$$\mathbf{g}^{LAV} = \begin{pmatrix} 0 \\ 0 \\ -g \end{pmatrix}$$

Sensor-Observation

DFHBF- Input 4/ Physical Obs.

- at the current time the Spherical Cap Harmonics methode is applied , and still in Revision and testing phase.

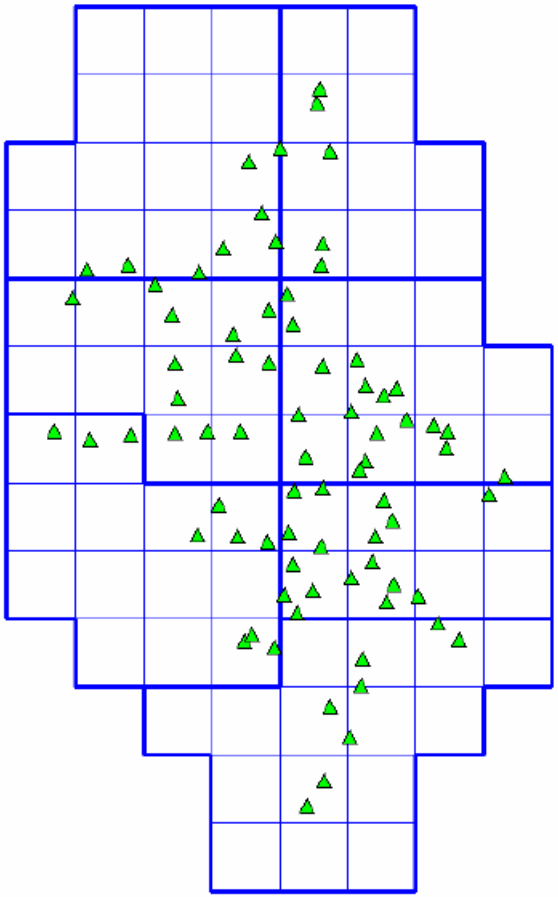
$$0 + v_{\Delta N} = N(C'_{n(k),m}, S'_{n(k),m}) - (\mathbf{f}^T \cdot \mathbf{p} + \Delta m \cdot h)$$



$$g^{SCH}_{grav\ r} = \sum_{k=0}^{\infty} \left(\frac{a}{r}\right)^{n(k)+1} \frac{(n(k)+1)}{r} \sum_{m=0}^{k} (C'_{n(k)),m} \cdot \cos m\lambda' + S'_{n(k),m} \cdot \sin m\lambda') \cdot P_{n(k),m}(\cos\theta') + dg(\mathbf{d}_g)$$

DFHBF

DFHBF- Accuracy - Factors



Meshsize

- 20-30 km : HRS approximation error < (5-10) cm
- 10 km: HRS approximation error <1 cm
- 5 km: HRS approximation error < 0.5 cm

Fitting Point Density (< 10 mm points, EGG97)

- 50 points per (100 km x 100 km): <_1_cm DFHRS_DB
- 10 points per (100 km x 100 km): < 3_cm DFHRS_DB
- 3-4 points per (100 km x100 km): < 5-10_cm DFHRS_DB

Patch-Size (EGG97)

(3-5) points per patch

- 30 - 40 km for a < 1_cm DFHRS_DB
- 50 – 60 km for a < 3_cm DFHRS_DB
- 300 km for a < 10_cm DFHRS_DB

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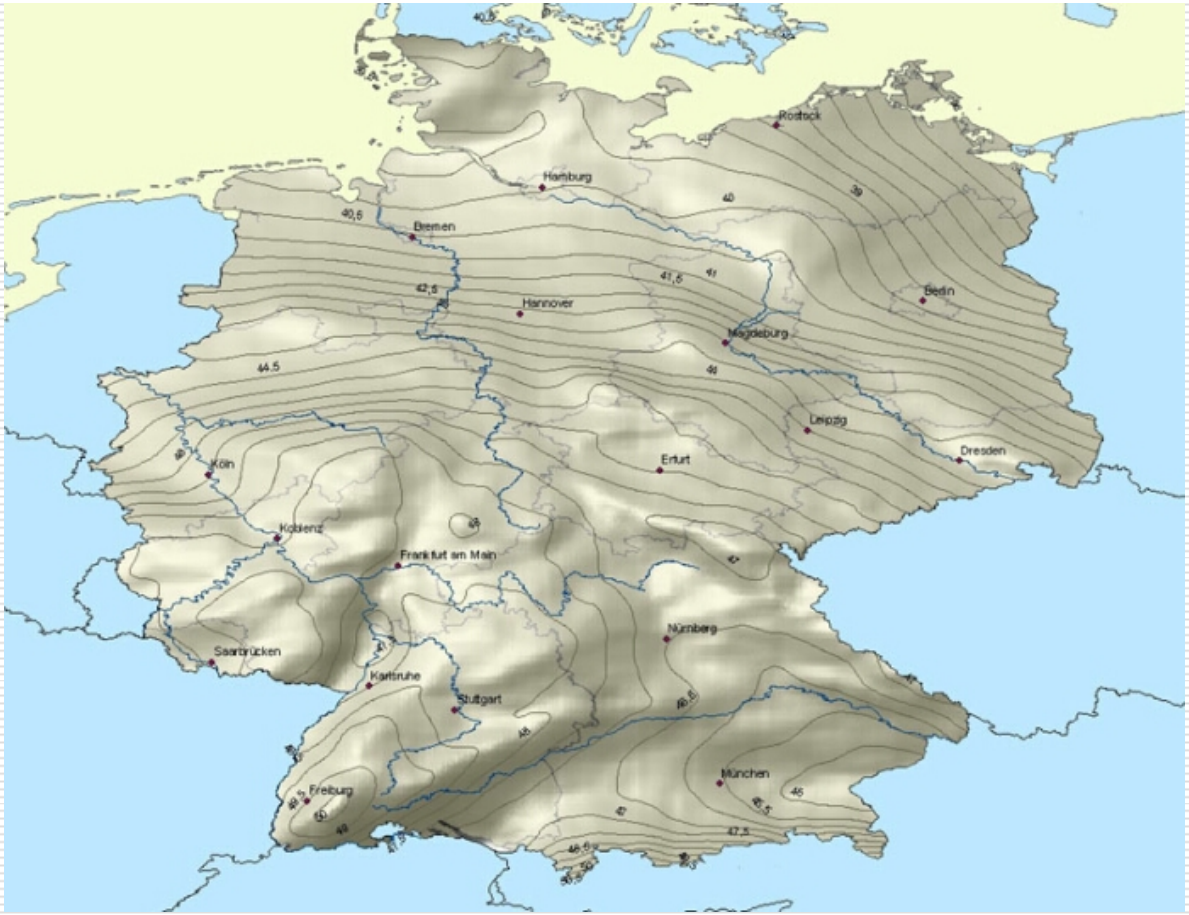
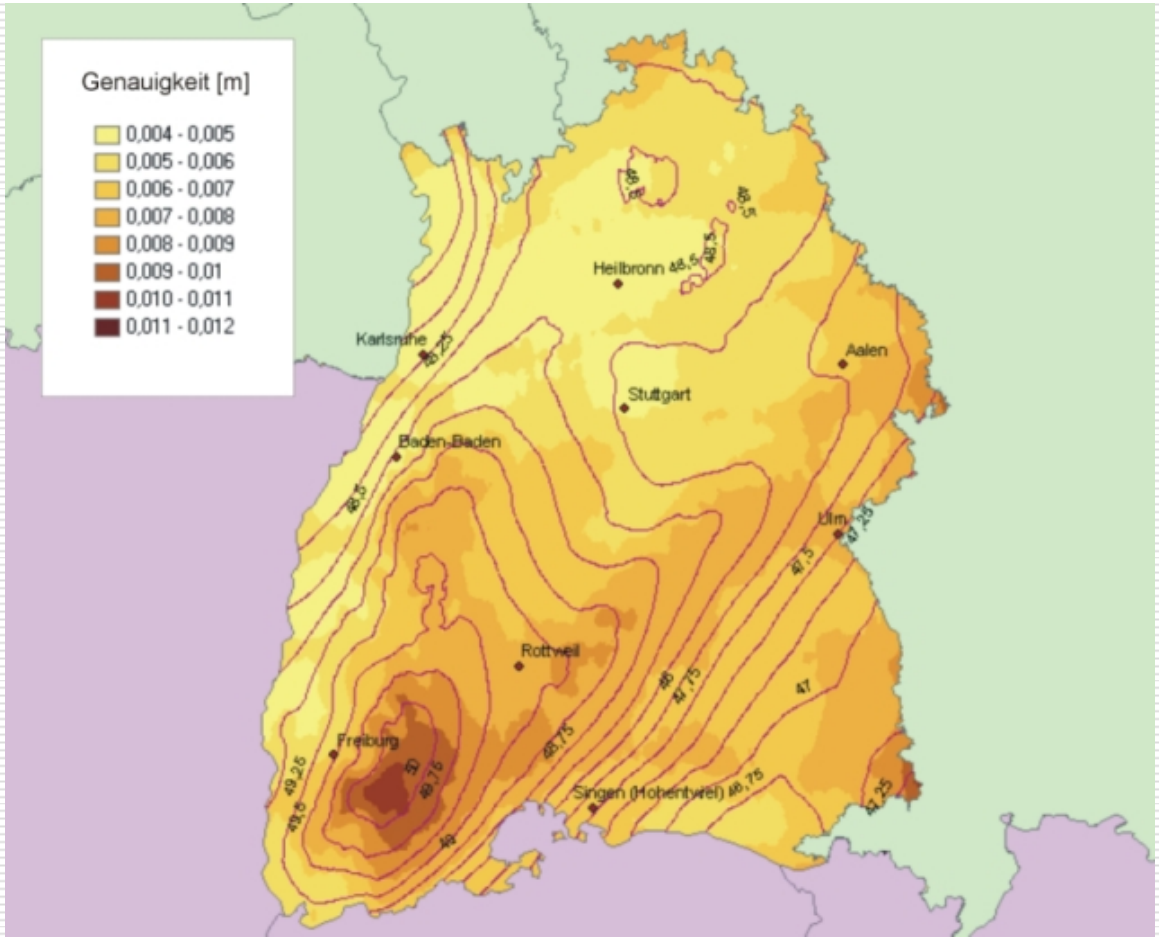
DFHBF- Projects
Germany: Germany 1-2 cm

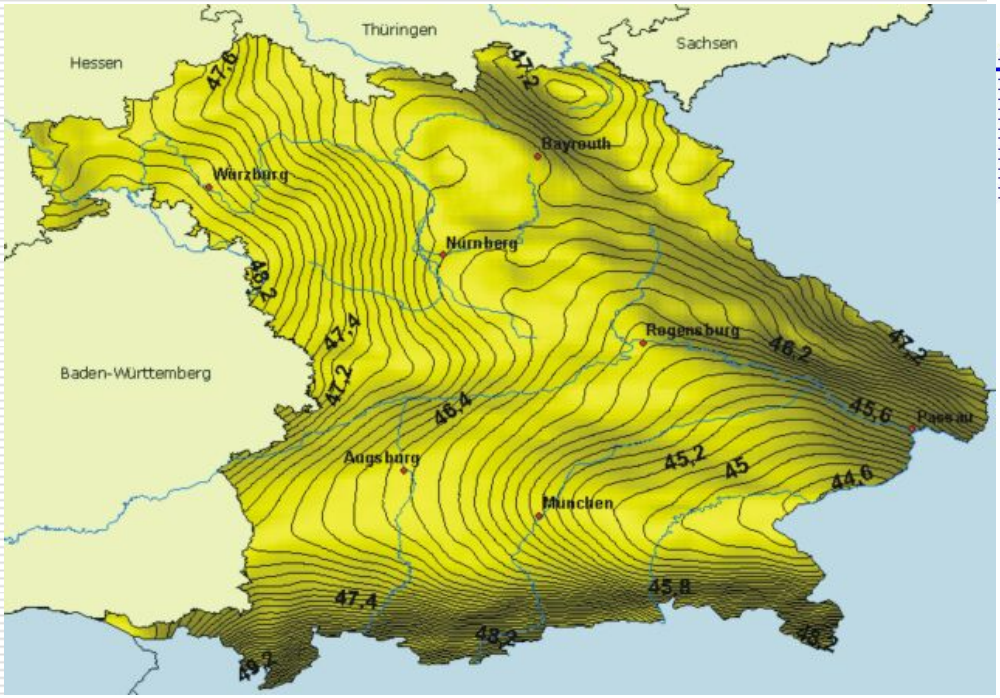


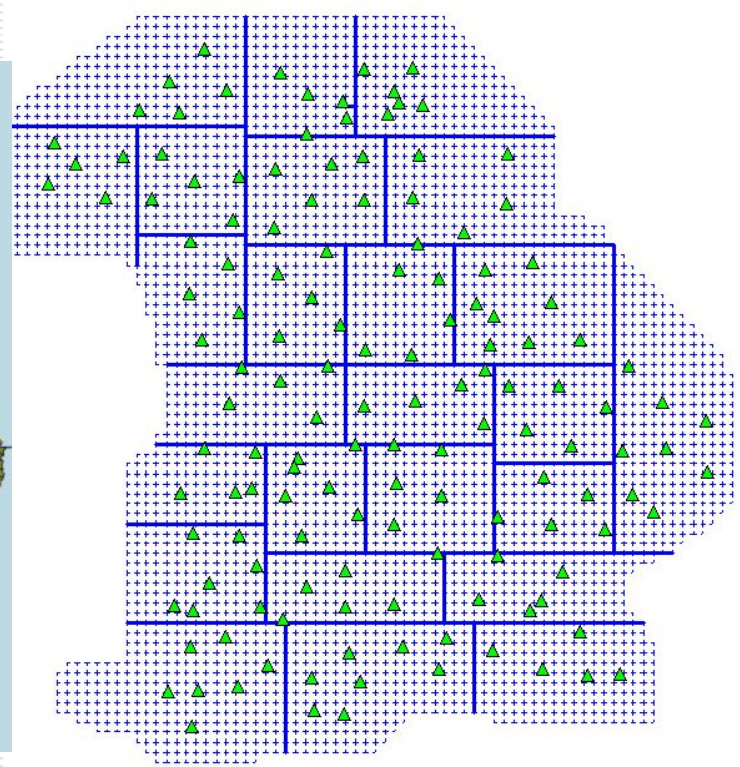
DFHBF- Projects
Germany: Baden - Württemberg 1 cm



DFHBF- Projects
Germany: Bayer

5km x 5 km FEM-Meshing of the DFHRS-Bayern. To reduce systematical error in the group of geoid-observation, 25 geoidpatches with own set of datum parameters were introduced





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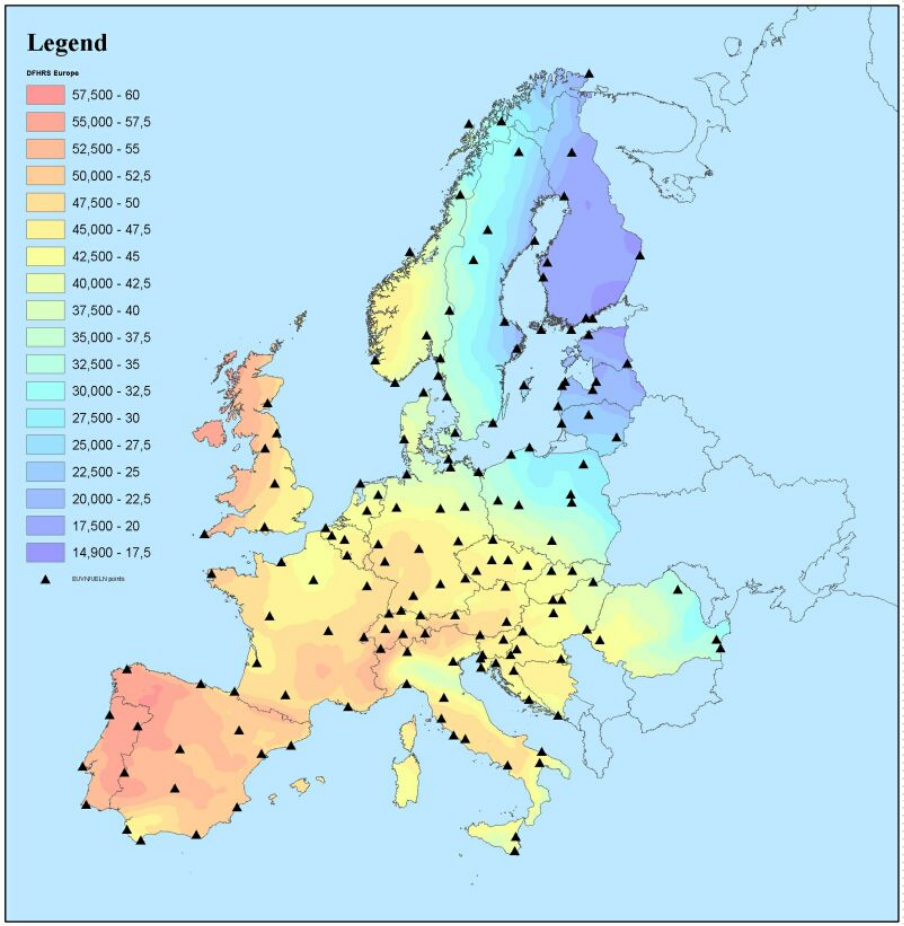
DFHBF- Projects Germany:

yellow: precise 1cm

orange + yellow: (1-3) cm

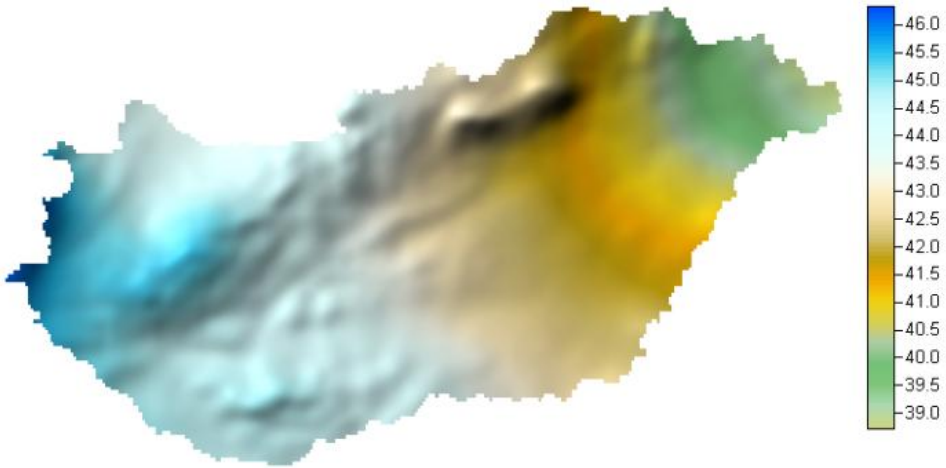
blue: (1-3) cm DFHRS-databases of Luxemburg

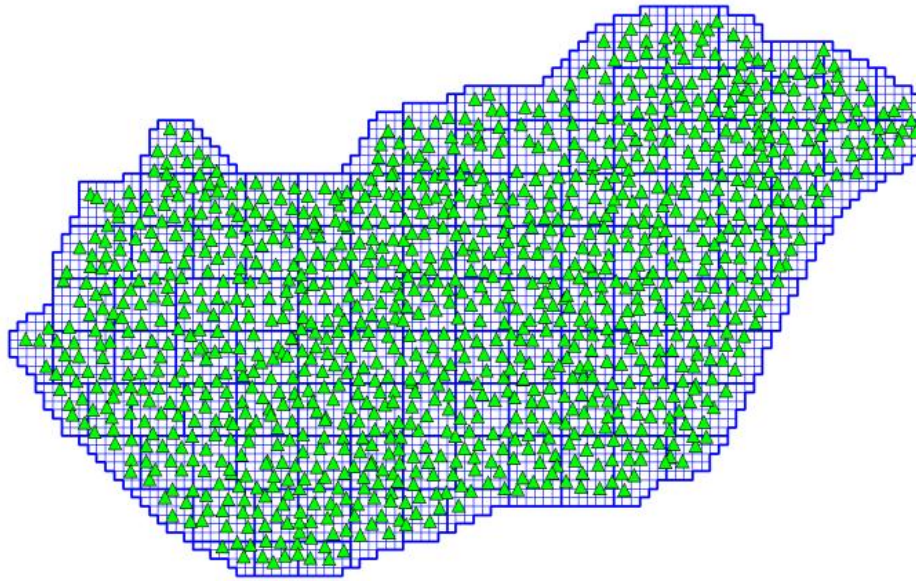
DFHBF- Projects
Europe: <10 cm



DFHBF- Projects
Europe: Hungery <1 cm

The mesh and patch design. Mesh size is 5 km x 5 km



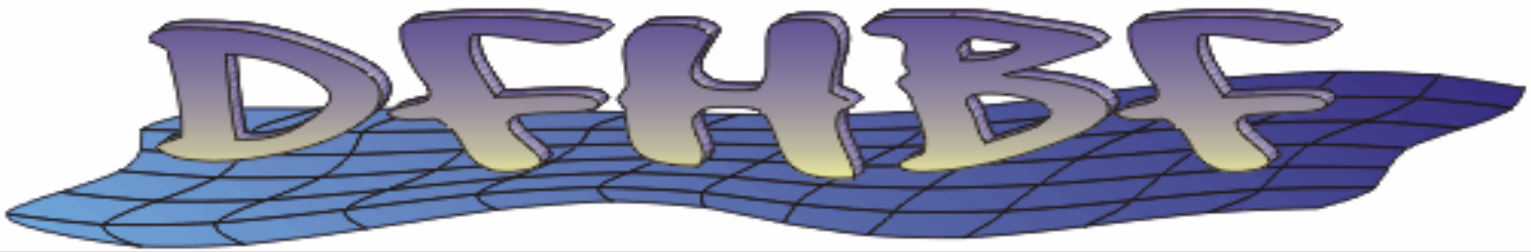


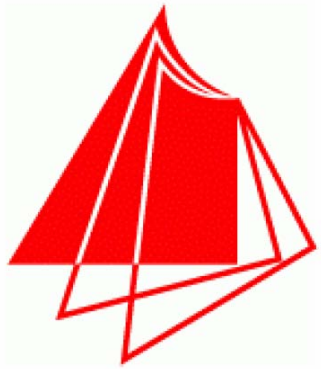
DFHBF

DFHBF- Projects Europe & world:

- DFHRS - Baltic
- DFHRS - Estonia
- DFHRS - Latvia
- DFHRS - Lithuania
- DFHRS - Luxembourg
- DFHRS - Albania
- DFHRS - Troia
- DFHRS – Hungary
- DFHRS - Namibia
- DFHRS - Windhoek
- DFHRS - Florida

Hochschule Karlsruhe Technik und Wirtschaft
University of Applied Sciences





THANKS

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http://www.dfhbf.de