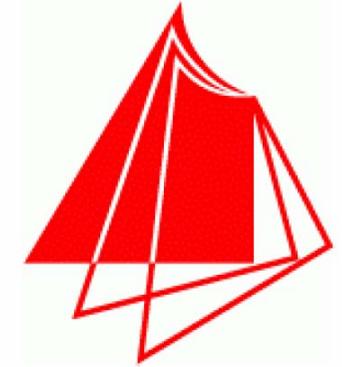


# Digital Finite-Element Height Reference Surface (DFHRS)

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By:

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PhD. Student, HS-Karlsruhe/TU-Darmstadt, since Oct.2008.

Responsible for further development of DFHBF .

Nov.2010





## DFHRS (DFHBF-Software)

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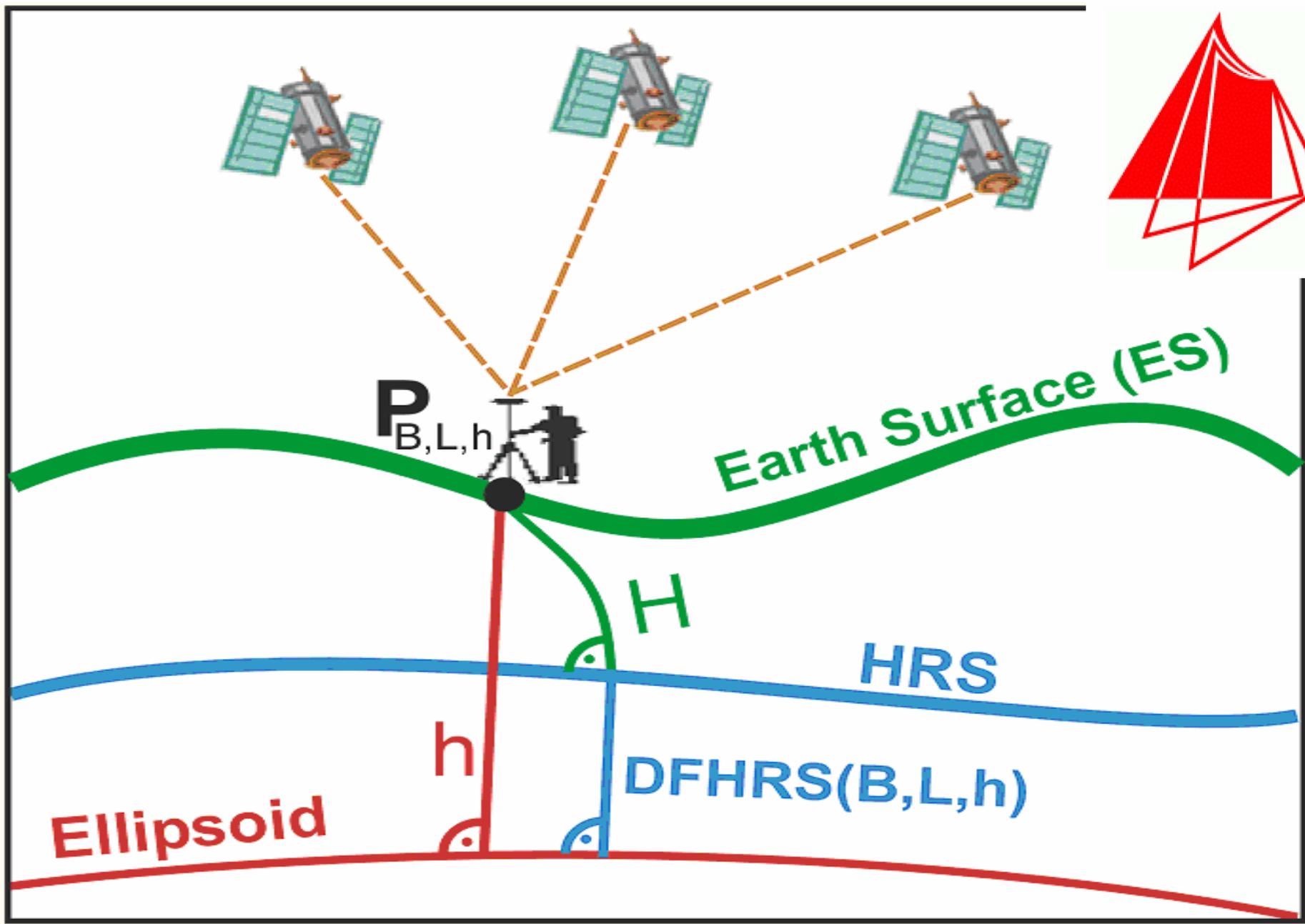
- Digital Finite-Element Height Reference Surface => DFHRS
- Digitale Finite-Element Höhen- Bezugs-Fläche => DFHBF.

[www.dfhbf.de](http://www.dfhbf.de)

[www.geozilla.de](http://www.geozilla.de)

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



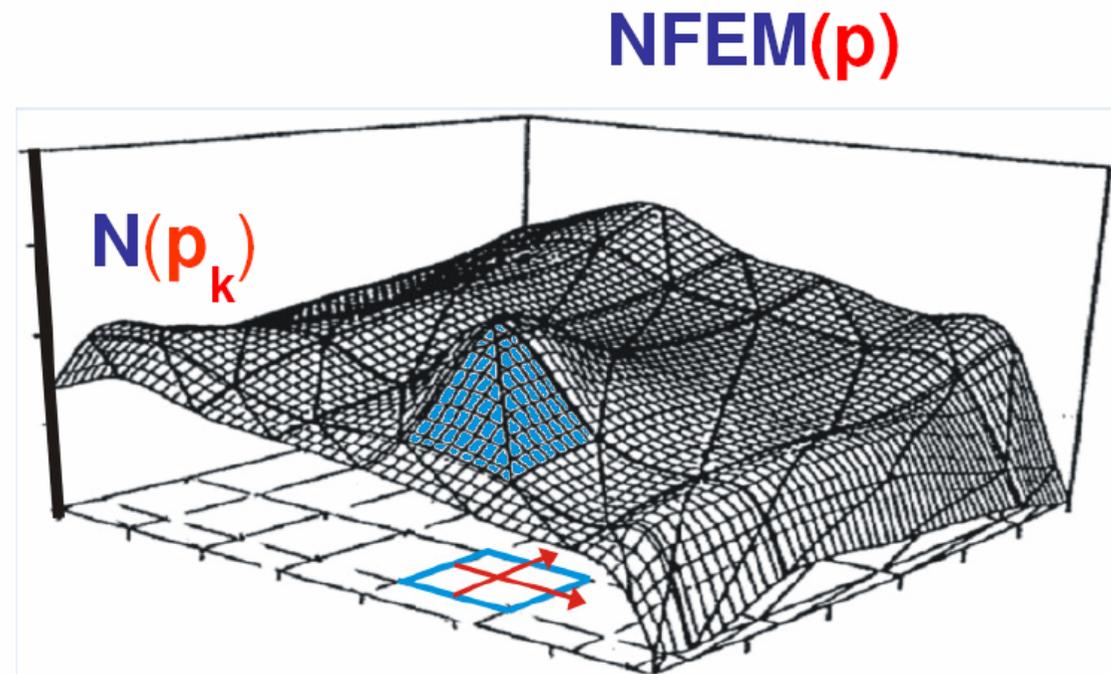


DFHBF



## 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 polynomial.
- Continuity condition between all elements is considered to have a continuous surface.
- The calculated parameters are stored in a database : DFHBF\_DB.



DFHBF

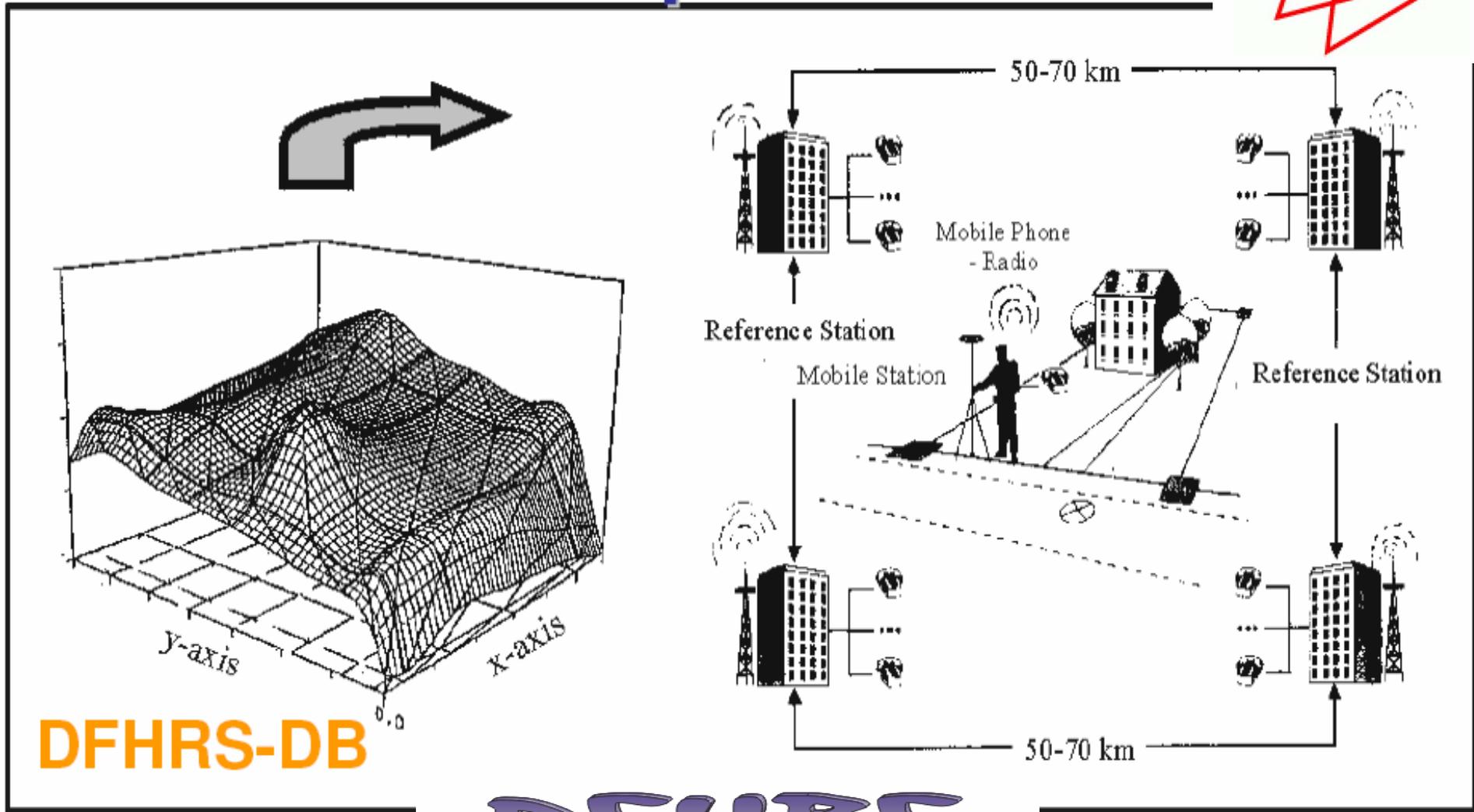


## DFHBF-Idea 2/2

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





**DFHRS-DB**

**DFHBF**



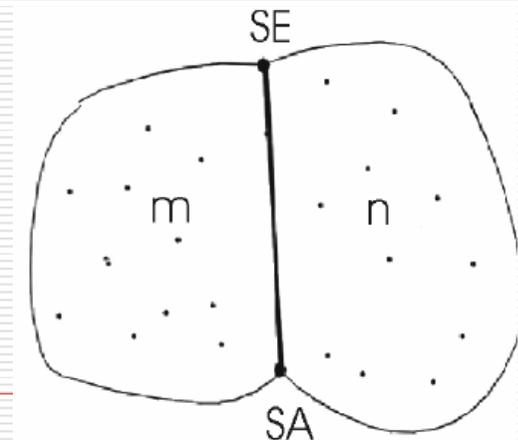
## DFHBF-Concept 1/2

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

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

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

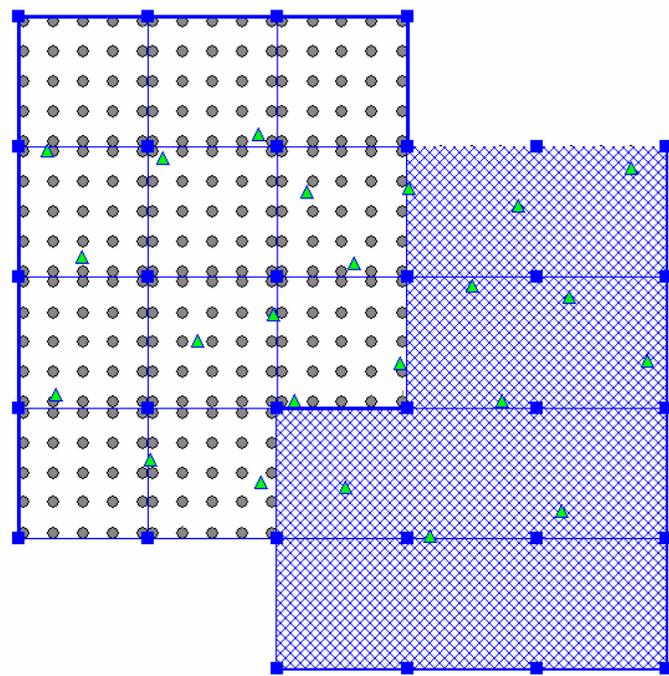
$$\mathbf{N}_{\text{FEM}} = \left\{ \begin{array}{l} \mathbf{N}(\mathbf{p}_k) = \sum_{i=0}^l \sum_{j=0}^{l-i} a_{ij,k} \cdot y^i x^j = \mathbf{f}^T \cdot \mathbf{p}_k \\ C_{0,1,2}(\mathbf{p}_m; \mathbf{p}_n) \end{array} \right\}$$





## DFHBF-Concept 2/2

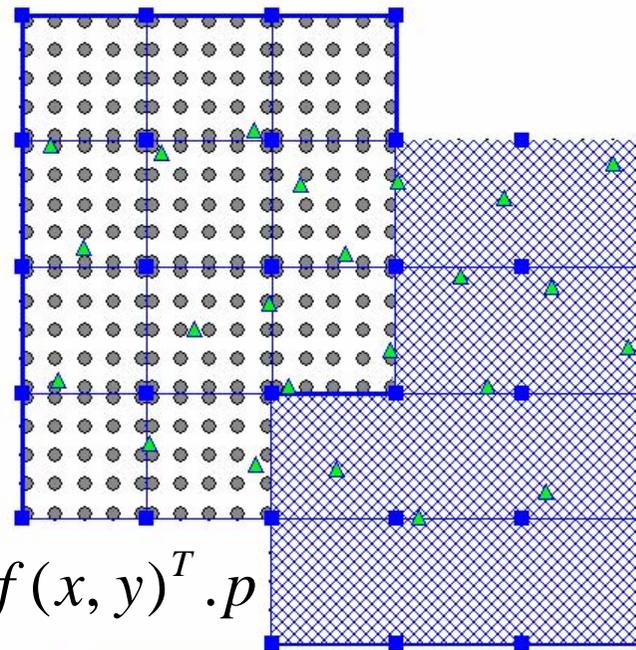
- Each group of meshes form a Patch.
- This allows applying datum corrections for different groups of observations.





# DFHBF- Input 1 / fixed points

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



**Festpunkte einlesen**

Festpunktdatei mit Koordinaten im Zielsystem:

Koordinatentyp: Höhe

Höhenangauigkeit, wenn nicht anders angegeben:  $s_H =$   m

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Festpunktdatei mit Höhen im Quellsystem:

Koordinatentyp: Breite, Länge, Höhe [dezimal]

Bezugsellipsoid: WGS 84

Höhenangauigkeit, wenn nicht anders angegeben:  $s_h =$   m

OK  Abbrechen

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

**fp\_BLh - Editor**

Datei	Bearbeiten	Format	Ansicht	?
55-1066	47.26727938	18.74496447	197.1590	
55-1119	47.34102912	18.70920495	178.6480	
55-1122	47.33631876	18.82700354	182.0920	
55-1205	47.35193585	18.92409843	205.0930	
55-1455	47.22769906	18.93984862	144.0070	
55-1605	47.31307643	18.97485903	144.5760	
55-2001	47.24754311	19.14309373	156.4650	
55-2125	47.31475202	19.07751231	148.7970	
55-2208	47.32810049	19.30582599	159.2520	

**Landeshoehen\_H - ...**

Datei	Bearbeiten	Format	Ansicht	?
55-1066	153.250			
55-1119	134.640			
55-1122	138.270			
55-1205	161.380			
55-1455	100.420			
55-1605	100.970			
55-2001	113.090			
55-2125	105.350			
55-2208	116.120			
55-2216	105.590			
55-2314	99.080			



## DFHBF- Input 2 /Global Potencial Models

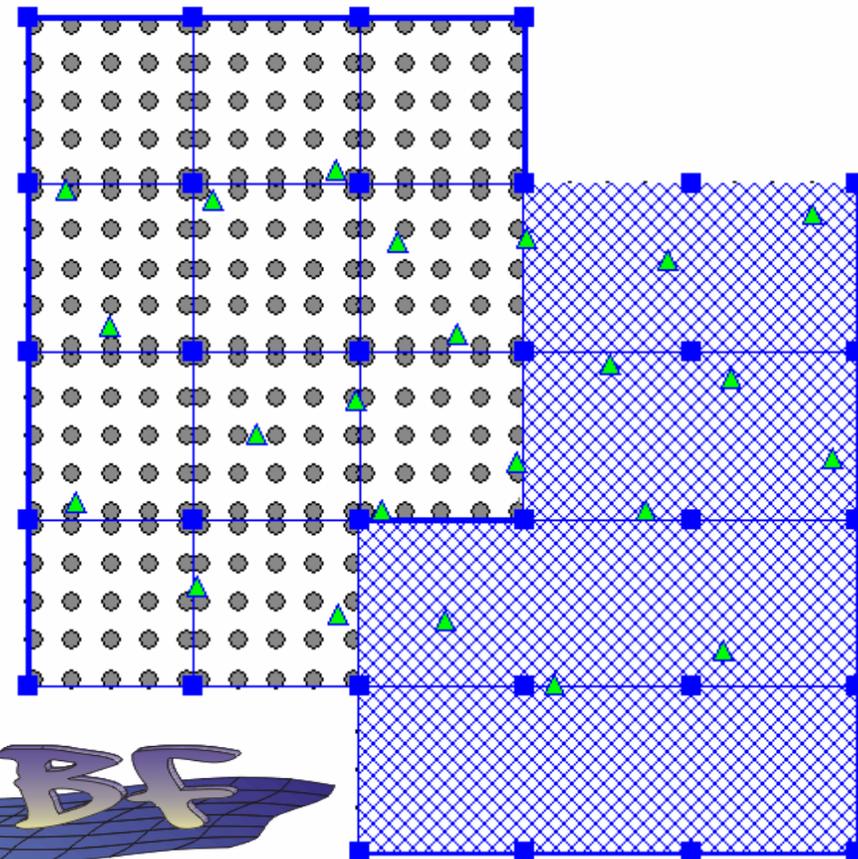
- In Global Potential Models -GPM are applied :EGM96 - Global, EGG97 –europe , Eigen05c.
- The Geoid Undulations:

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

- The Deflections of Vertical:

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

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





## DFHBF- Input 3 / Astronomical Obs.

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

$$\xi^j + \nu = \frac{-f_B^T}{M(\phi)} \cdot p + \partial \xi(d_{\eta, \xi}^j)$$

$$\eta^j + \nu = \frac{-f_L^T}{N(\phi) \cdot \cos(\phi)} \cdot p + \partial \eta(d_{\eta, \xi}^j)$$

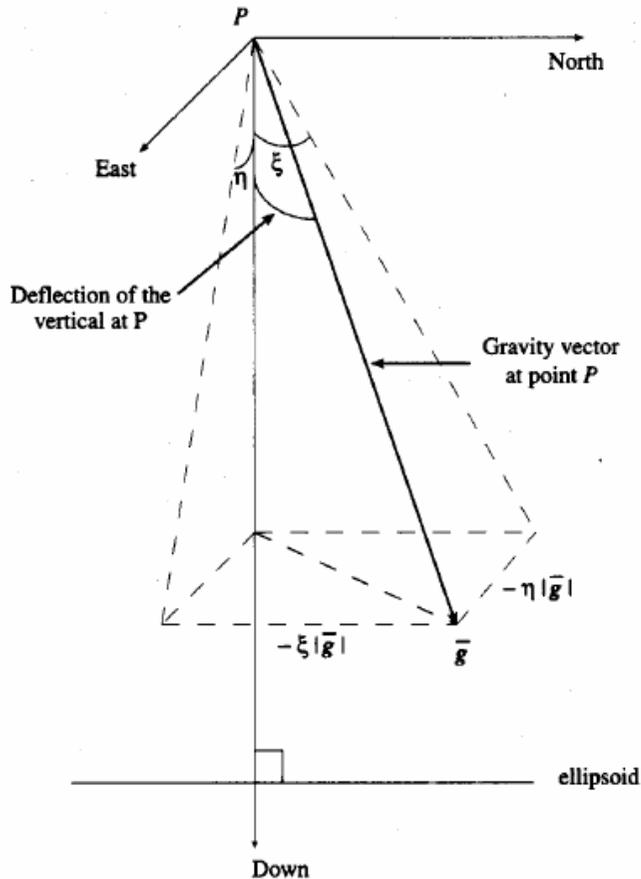




# DFHBF 5.0 (under development)

## Input 4/ Physical Obs.

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



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

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

Sensor-Observation

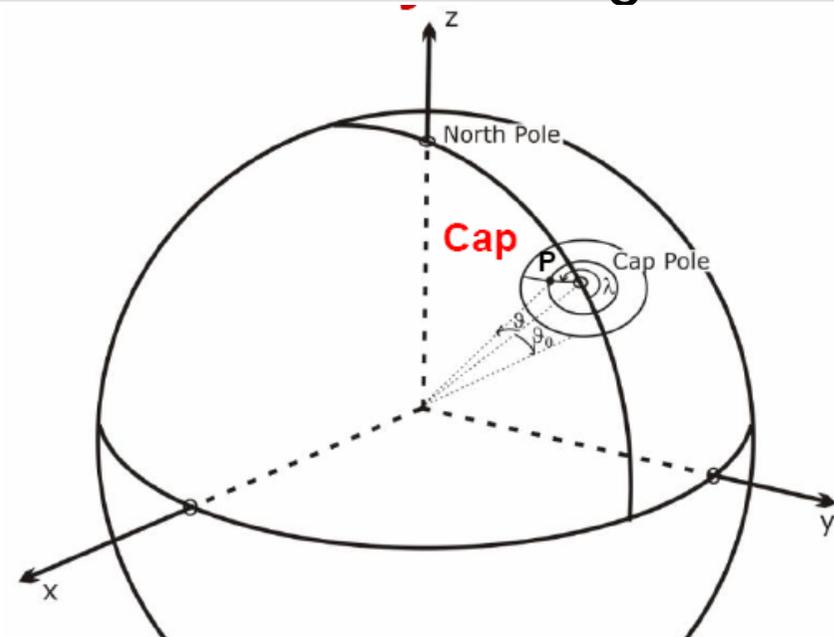


## DFHBF 5.0 (under development)

### DFHBF- Input 4/ Physical Obs.

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

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

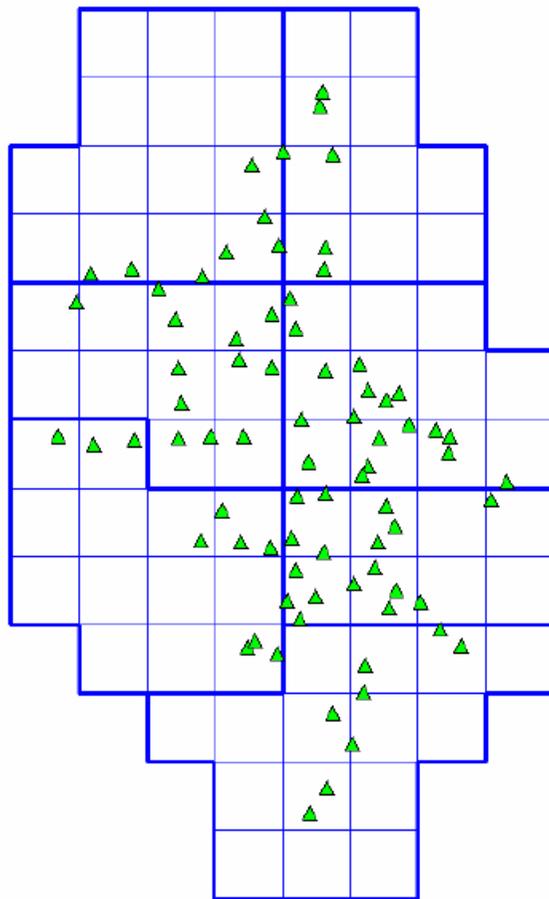


$$g_{grav\ r}^{SCH} = \sum_{k=0}^{\infty} \left( \frac{a}{r} \right)^{n(k)+1} \frac{(n(k)+1)}{r} \sum_{m=0}^k (C'_{n(k),m} \cdot \cos m\lambda' + S'_{n(k),m} \cdot \sin m\lambda') \cdot P_{n(k),m}(\cos \theta') + dg(\mathbf{d}_g)$$





## DFHBF- 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 x 100 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





# DFHBF- Projects

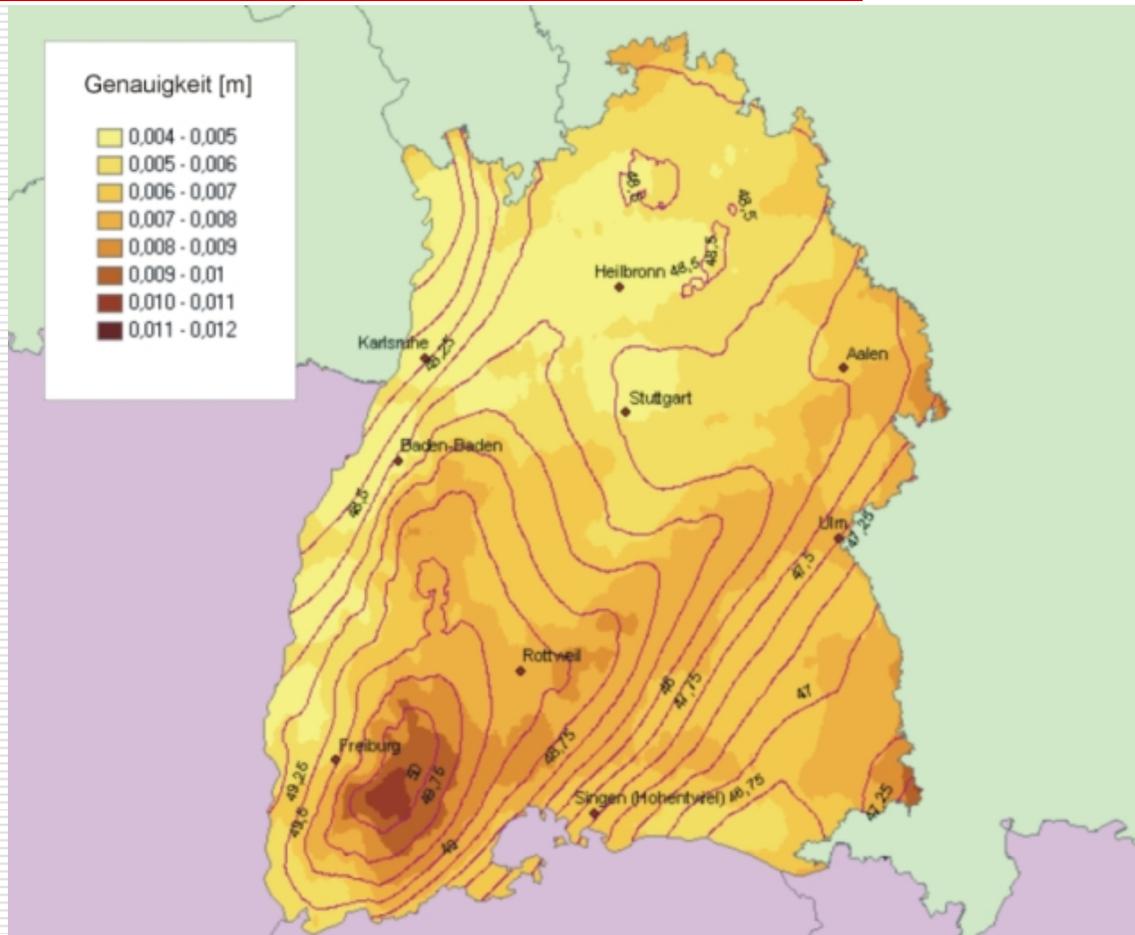
## Germany: Germany 1-2 cm





# DFHBF- Projects

## Germany: Baden - Württemberg 1 cm

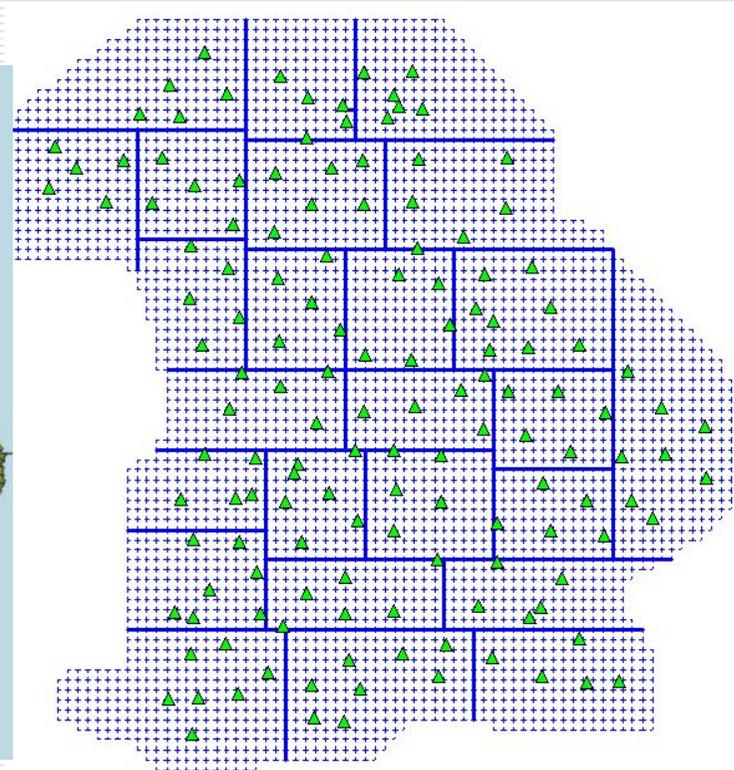
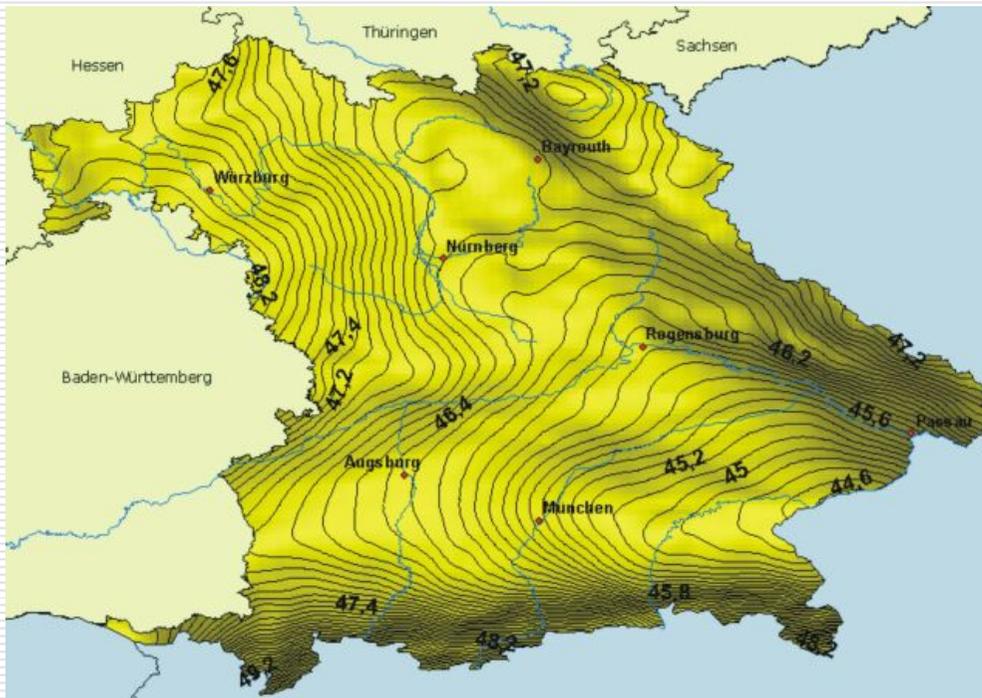




# DFHBF- Projects

## Germany: Bayern < 1cm

*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*





# DFHBF- Projects Germany:

**yellow:** precise 1cm

**orange + yellow:** (1-3) cm

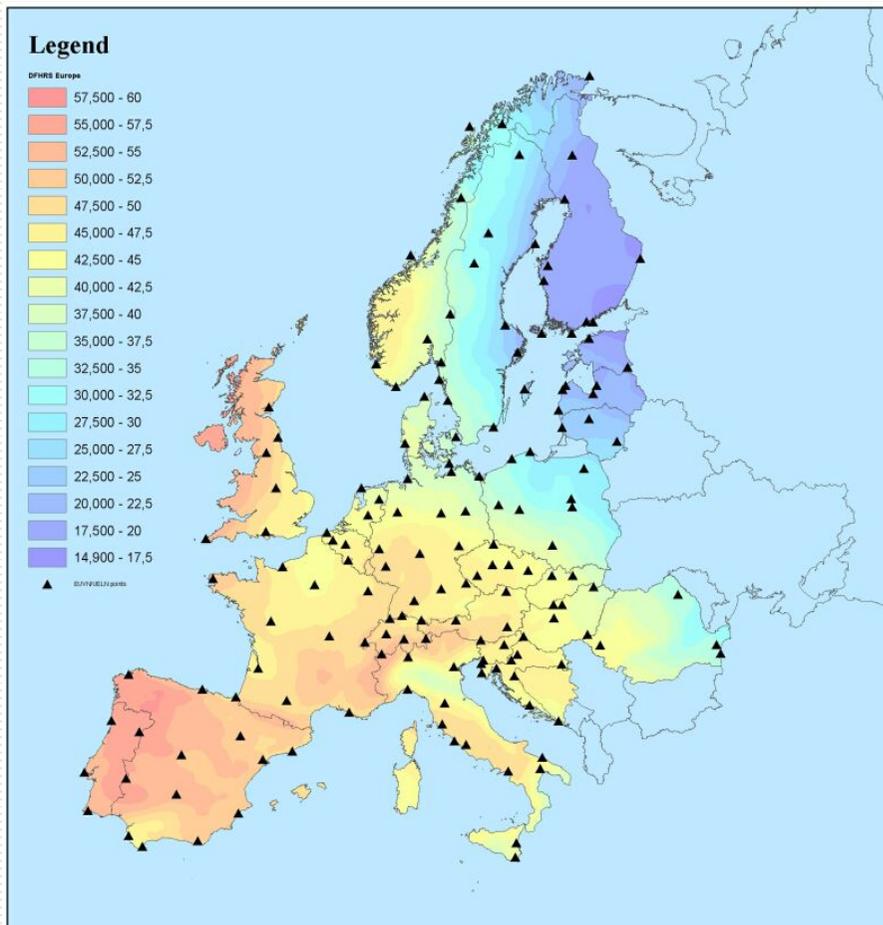
**blue:** (1-3) cm DFHRS-  
databases of Luxemburg





## DFHBF- Projects

Europe: <10 cm



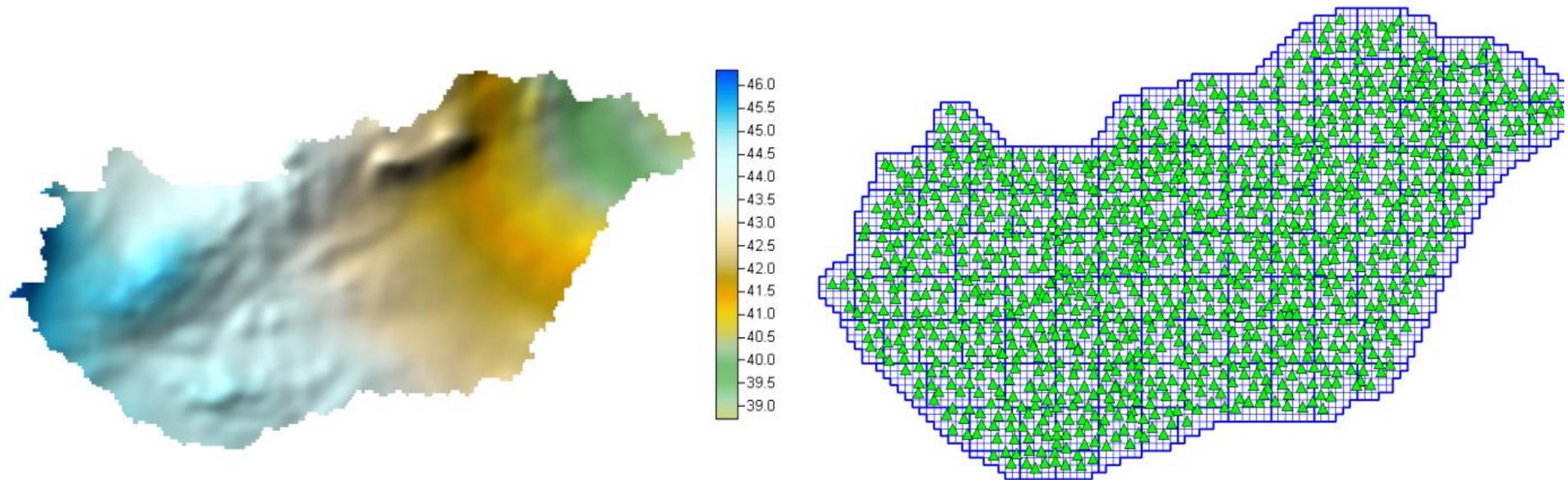
DFHBF

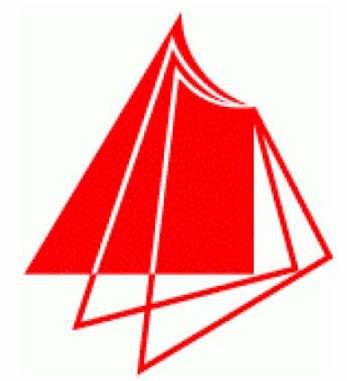


# DFHBF- Projects

## Europe: Hungary < 1 cm

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





## DFHBF- Moldova

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- Two height systems are available
- Baltic : available in the main cities
- Baltic77 : all over the country
- The mesh and patch design. Mesh size is 5 km x 5 km

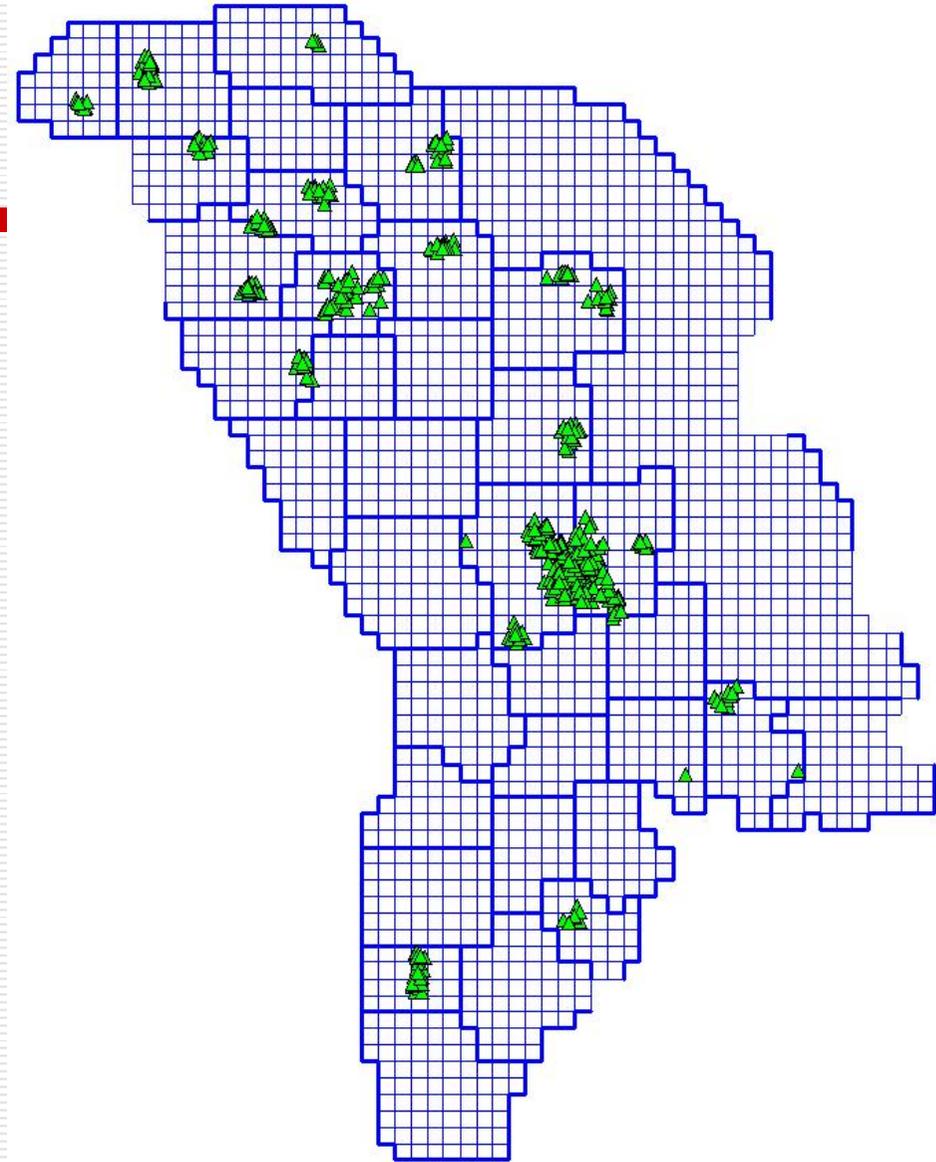




## DFHBF- Moldova

**Baltic** - old datum 1-2 cm

- Mesh design : 5x5 km
- 472 used Control points are concentrated in the main cities
- Residuals less than 5cm .
- Usable only in the main Cities shown in the figure

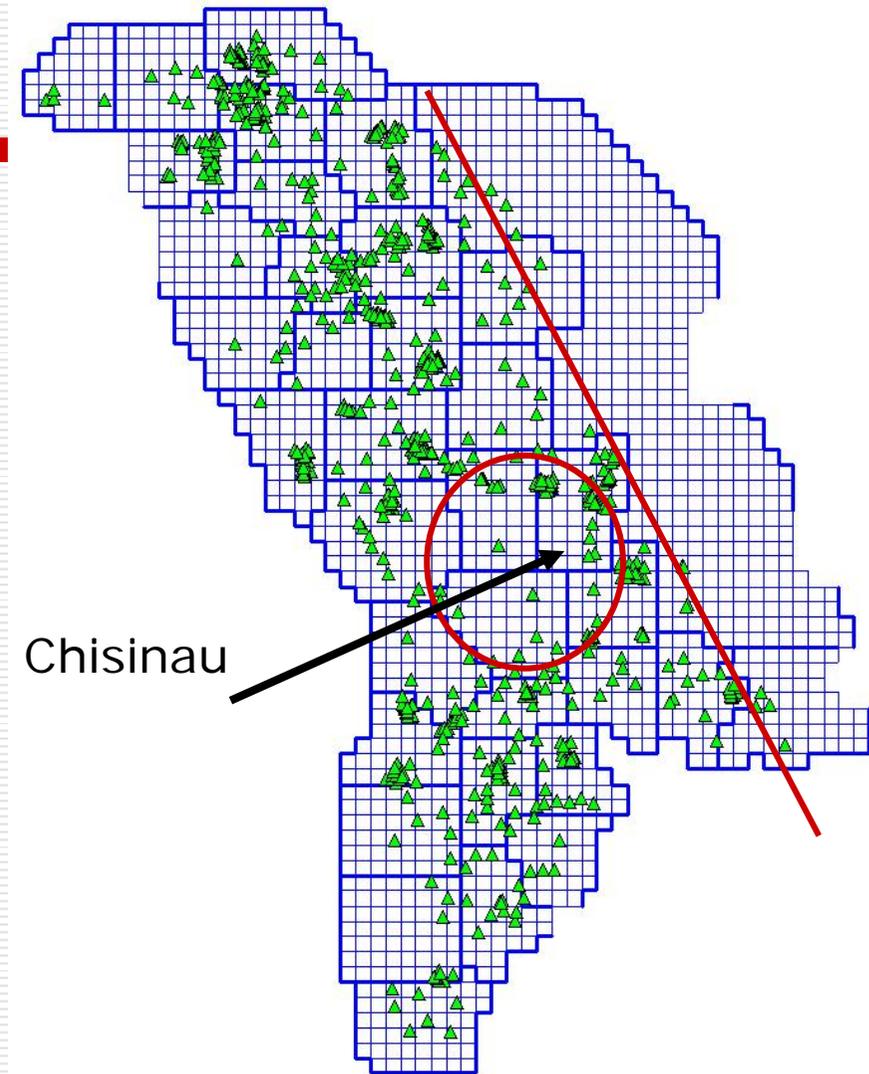




## DFHBF- Moldova

**Baltic77 : 1-2 cm**

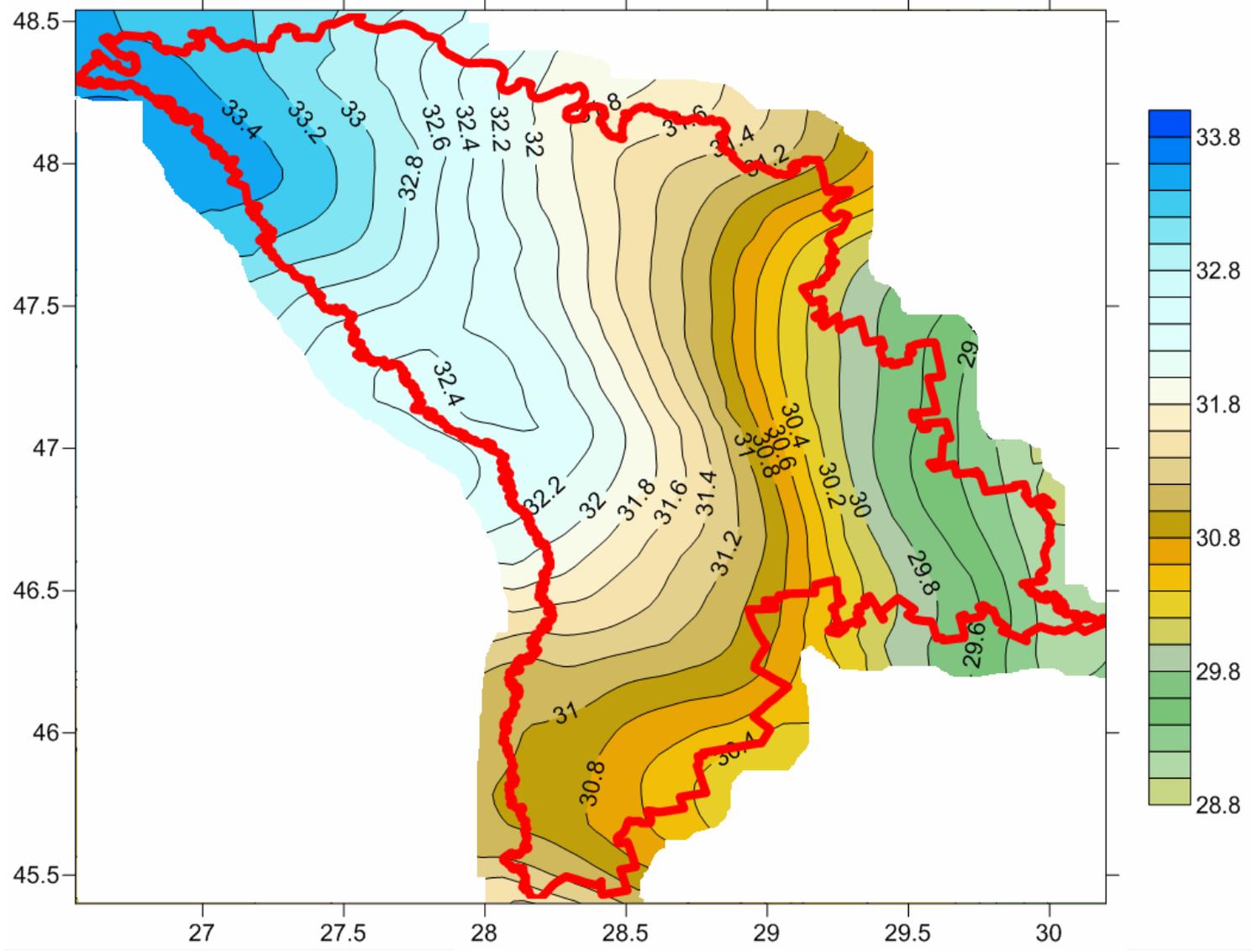
- Mesh design : 5x5 km
- 472 used Control points are distributed all over the country.
- Residuals less than 6cm .
- No control over the eastern areas in the country .
- Pure density in Chisinau area compared to the rest of the country

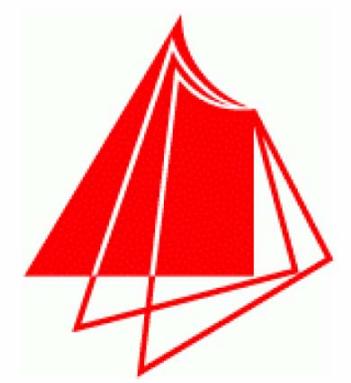




# DFHBF- Moldova

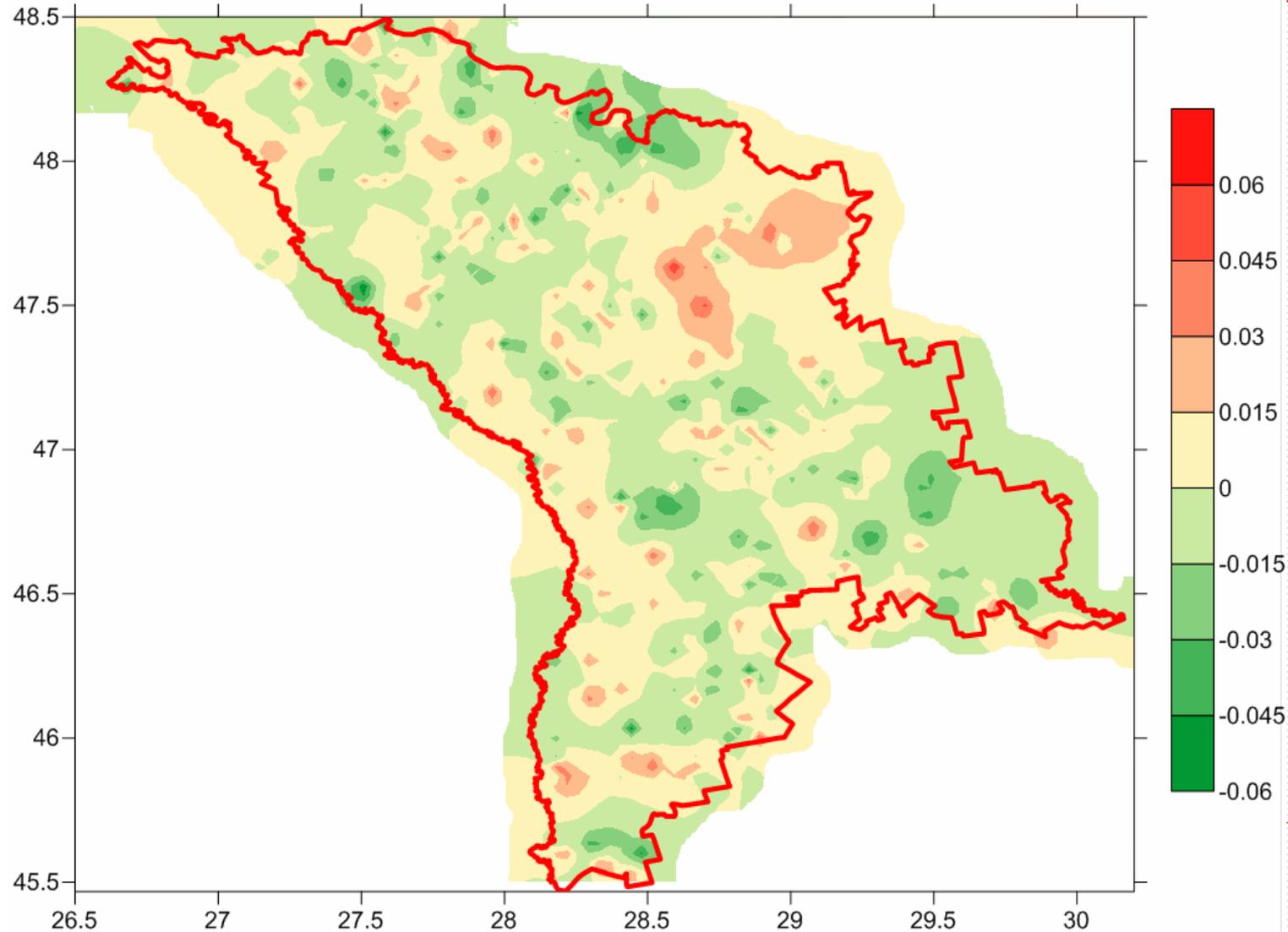
Baltic77 < 2 cm

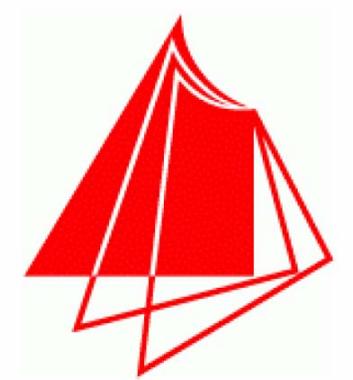




# DFHBF- Moldova

**Baltic77** - Residuals - 1-2 cm





## DFHBF- Projects Europe & world:

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Other world wide projects :

[DFHRS - Baltic](#)

[DFHRS - Estonia](#)

[DFHRS - Latvia](#)

[DFHRS - Lithuania](#)

[DFHRS - Luxembourg](#)

[DFHRS - Albania](#)

[DFHRS - Troia](#)

[DFHRS – Hungary](#)

[DFHRS - Namibia](#)

[DFHRS - Windhoek](#)

[DFHRS – Florida](#)

Current Project :

DFHRS-Canari Islands

DFHRS-Brazil





## DFHBF- Lastest Updates

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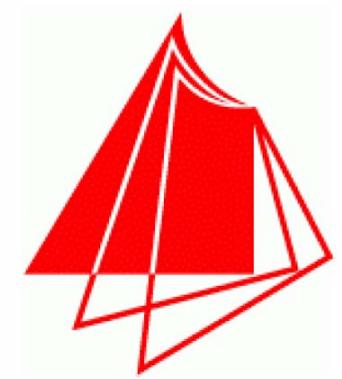
**DFHBF4.1** : EGM96, Eigen05, Egm2008 are Integrated

**DFHBF4.2** : 1- DTM2006 is Integrated to get H .  
2- Calculation of both Geoid (Orthometric Heights) and Quasi-Geoid (Normal Heights) is possible

**DFHBF5.0** : **Under Development**

DFHBF will be able to calculate the Height reference surface as an Equipotential model using spherical cap harmonics. where gravity data can be used as Input and also can be Interpolated as well as the height anomalies and deflections of vertical.





# THANKS

## Contacts:

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