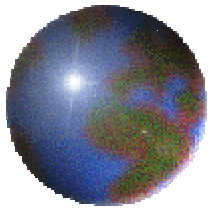
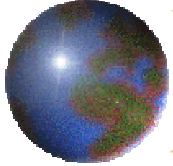


THE CHANGE OF NATIONAL DATUM IN FINLAND

Reino Ruotsalainen, NLS

Nordisk Teknikermöte, 7.10.2003



ETRS89
European Terrestrial Reference System 1989

The IAG Subcommision for the European Reference Frame (EUREF) recommends that the terrestrial reference system to be adopted by EUREF will be coincident with ITRS at the epoch 1989.0 and fixed to the stable part of the Eurasian Plate. It will be named European Terrestrial Reference System 89 (ETRS89).

EUREF-FIN (= ETRF89)

The realisation of ETRS89 in Finland is defined by the national recommendation (Ministry of Interior).

JHS 153: ETRS89-järjestelmän mukaiset koordinaatit Suomessa

(I.e. "ETRS89 coordinates in Finland")

http://www.intermin.fi/intermin/hankkeet/juhta/home.nsf/pages/indexfin

National recommendation 154:

"Map projections, plane coordinates and map sheet index in the connection of ETRS89 coordinate system"

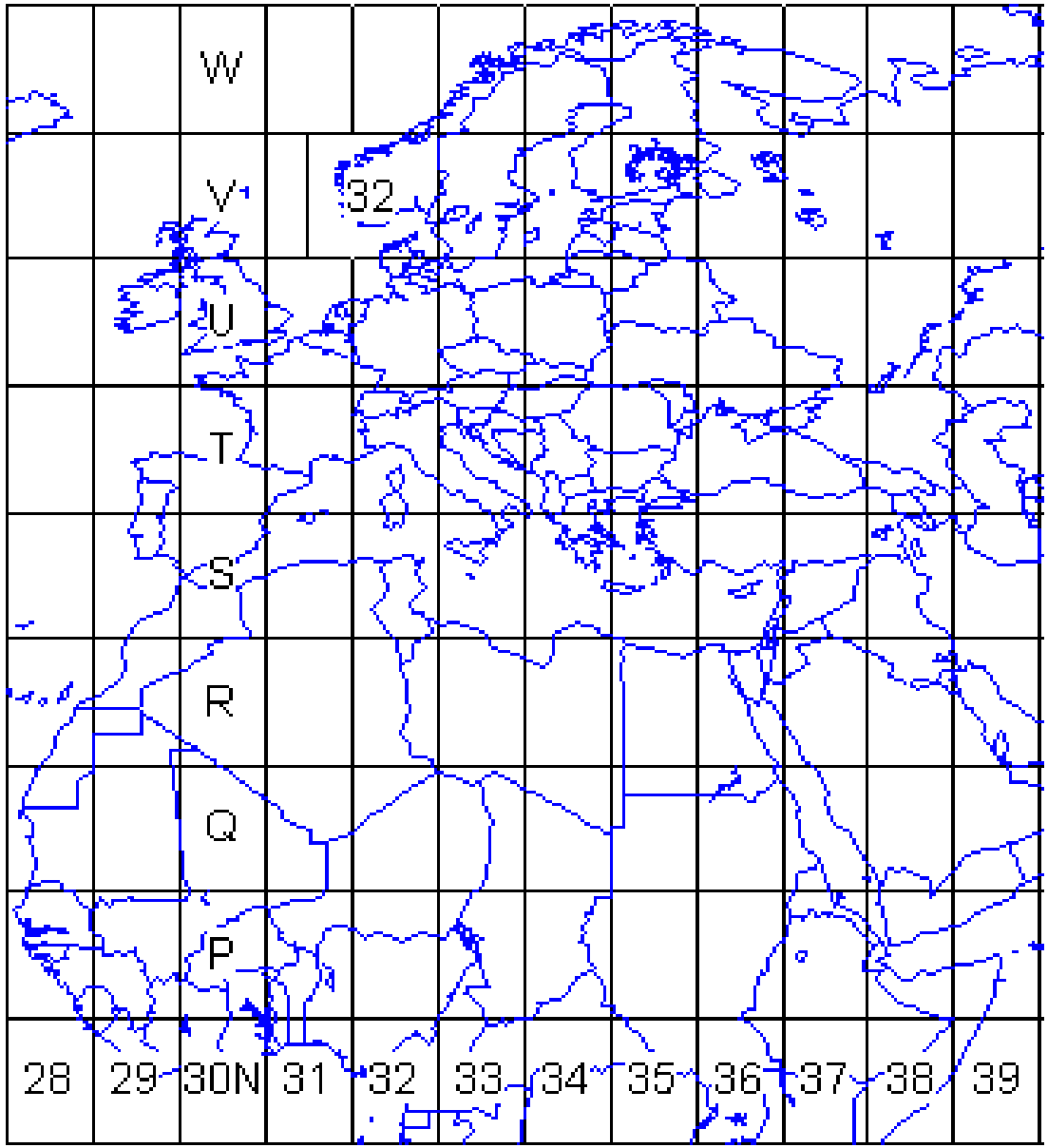
- Ministry of Interior gave the recommendation in June 2003
- It defines map projections, 2D-coordinate transformations and the recommended new map sheet index.

Differences between the old kkj-system and EUREF-FIN

- Kkj is 2D-coordinate system
- Hayford ellipsoid a=6378388 f=1/297
- Errors in realisation up to ± 2 m)

- geosentric 3D-koordinaatisto
- GRS80 ellipsoid a=6378137 f=1/298.257222101
- Accuracy of realisation few centimeters (country wide)

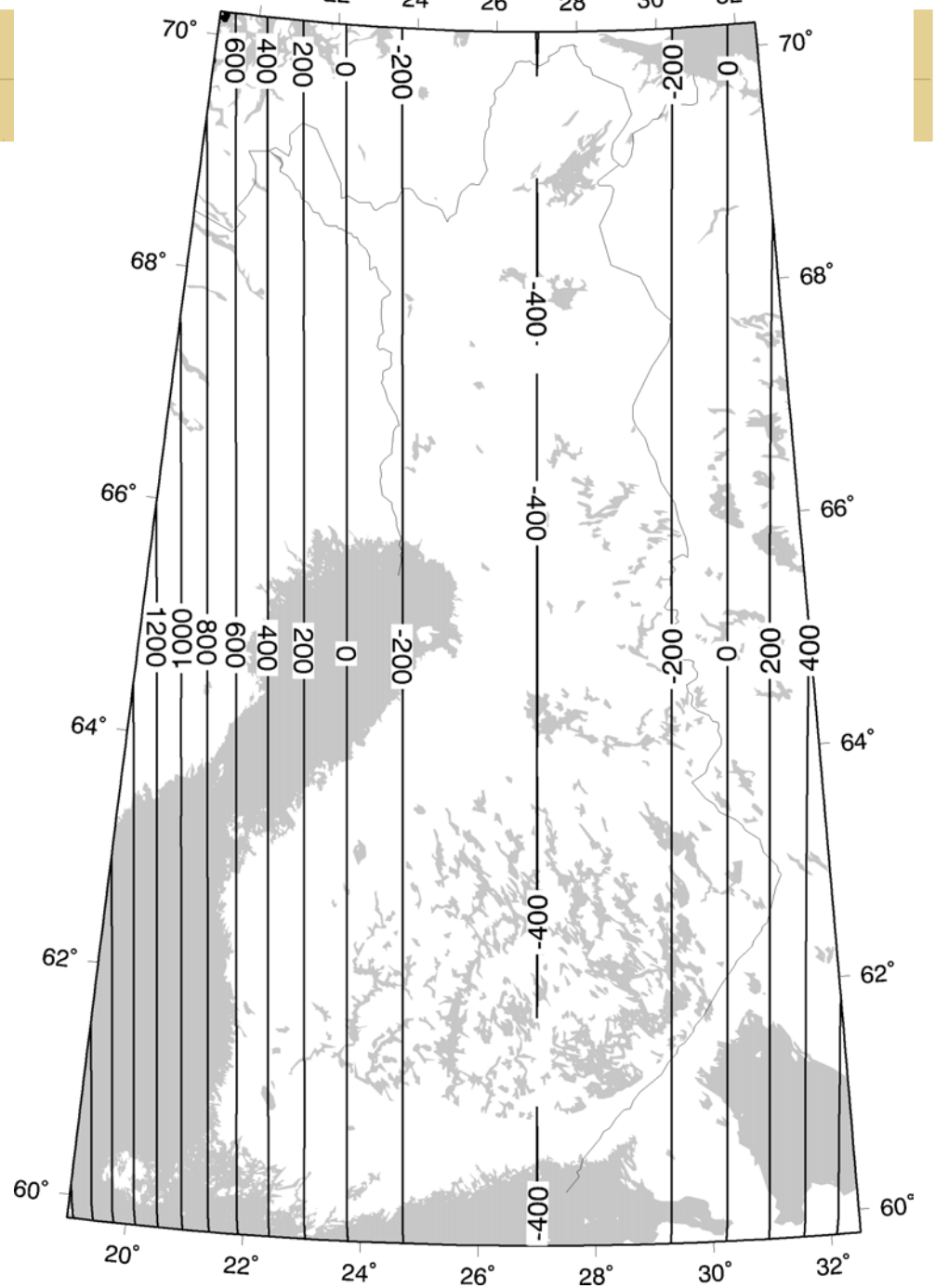
UTM-projection (standard grid)



ETRS-TM35FIN -projection

- The pan-European ETRS-TMzn-projection is recommended (in country wide use).
- The zone width is expanded covering the whole country (instead of the standard 6° of ETRS-TM –system). Projection is therefore called ETRS-TM35FIN.
- ETRS refers to the geodetic datum ETRS89 (EUREF-FIN) and TM35 (Transverse Mercator) refers to the number of projection zone, with the central meridian of 27°.

Scale correction (ppm)



Gauss-Krüger / ETRS-GKn – projection (for local use)

- As a parallel system Gauss-Krüger - projection can still be used, where the zone width of ETRS-TM –system is too large, for example in municipalities.
- The central meridian of Gauss-Krüger - projection can be the closest latitude degree (19°, 20°,… 31°). In this way the projection corrections are reasonable.

Gauss-Krüger / ETRS-GKn – projection (cont.)

- The projection is called ETRS-GKn, where n is the latitude of the central meridian, for example ETRS-GK27.
- The origin of the coordinate system is in the cross of equator and the central meridian of the zone. False easting of 500 000 m is used in order to avoid negative coordinate values.

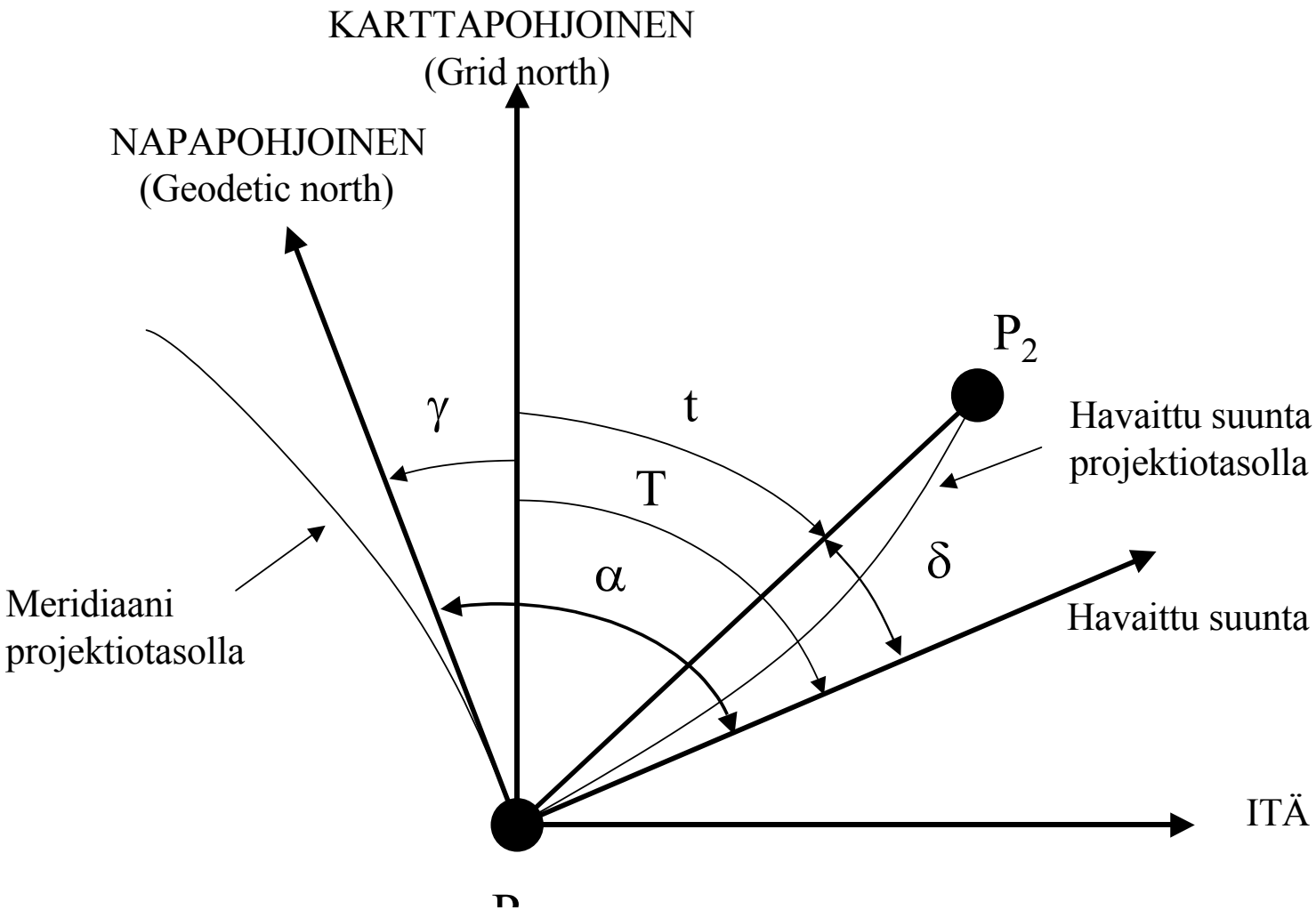
The Map Projections in Finland

Plane coordinates	ETRS-TM35FIN	ETRS-GKn	kkj
Map projection	UTM	Gauss-Krüger	Gauss-Krüger
Reference ellipsoid	GRS80	GRS80	International 1924
Central meridian(s)	27°	19°, 20°, 21°… 31°	18°,21°,24°,27°,30°,33°
Number of zones	1	13	6
The width of zones	n.13° (-8° - +5°)	1° (±0.5°)	3° (±1.5°)
False easting	500 000 m (8 500 000 m of special reasons)	500 000 m	n 500 000 m, where n = the zone number (0,1,2,3,4,5)
Scale factor at central meridian	0.9996	1.0	1.0

Projection calculations

- **Transformations:** (obs. accuracy !)
  - **From Geodetic coordinates (φ,λ) to plane coordinates (E, N)**
  - **From plane coordinates (E, N) to geodetic coordinates (φ,λ)**
- **Arc-to-chord Correction**
  - **δ = (t – T)**

Grid north, Geodetic north, meridian convergence and Arc-to-chord Correction



National recommendation 154:

"Map projections, plane coordinates and map sheet index in the connection of ETRS89 coordinate system"

- the whole country is covered by one UTM-zone (27°)
- coordinate axis are called **N** ja **E** (EUREF-plane coordinates
- transformation between the old and new system is done by affine triangles (virtual triangles outside of the country, except in Sweden)
- reason: it is easy to add new transformation points locally
- False easting of ETRS-TM35FIN is (like in standard UTM) 500 000 m (for special cases 8 500 000 m can be used)

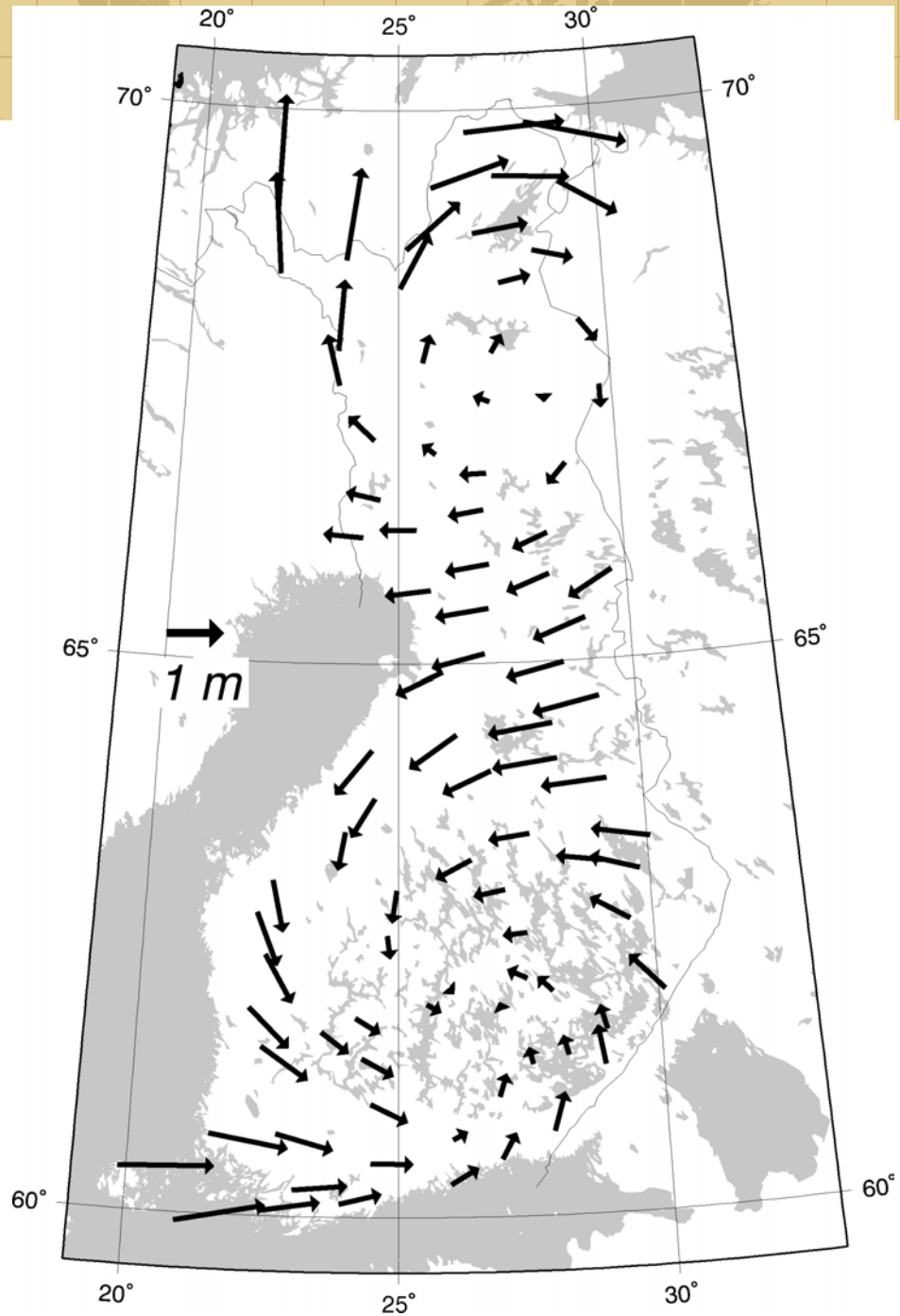
3D-transformation between EUREF-FIN and the old kkj-system

$$\begin{vmatrix} X \\ Y \\ Z \end{vmatrix}_{\text{kkj}} = (1+m) \cdot \begin{vmatrix} 1 & \varepsilon_z & -\varepsilon_y \\ -\varepsilon_z & 1 & \varepsilon_x \\ \varepsilon_y & -\varepsilon_x & 1 \end{vmatrix} \cdot \begin{vmatrix} X \\ Y \\ Z \end{vmatrix}_{\text{ETRF89}} + \begin{vmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{vmatrix}$$

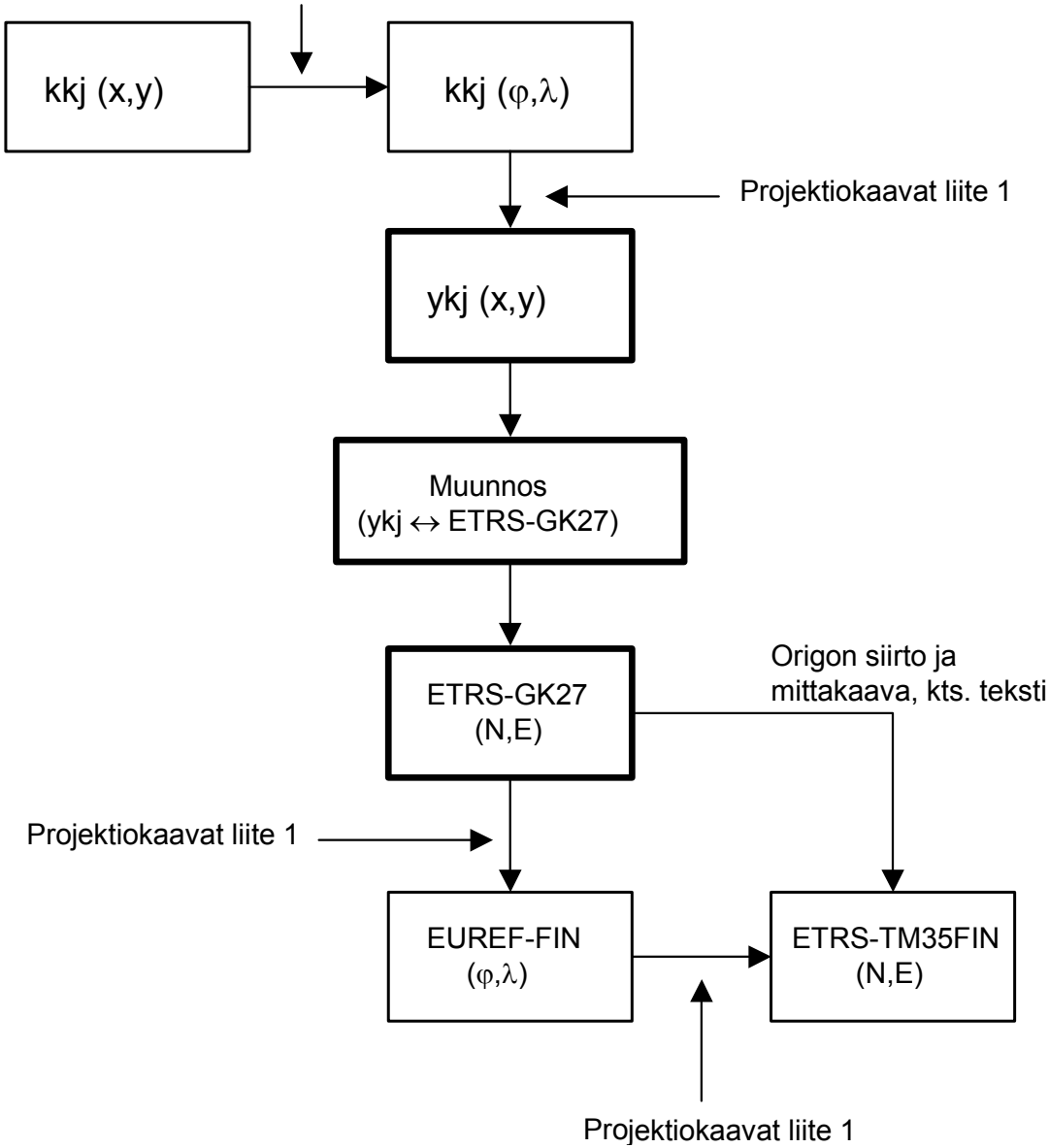
3D-transformation parameters between EUREF-FIN and kkj

	EUREF→ kkj	kkj→ EUREF	RMSE	Unit
ΔX	96.0610	-96.0617	±1.614	m
ΔY	82.4298	-82.4278	3.111	m
ΔZ	121.7485	-121.7535	1.141	m
εx	4.80109	-4.80107	0.093	sec.
εy	0.34546	-0.34543	0.049	sec.
εz	-1.37645	1.37646	0.056	sec.
m	-1.49651	1.49640	0.176	ppm

Residual errors of EUREF-FIN – kkj 7-parameter transformation



2D- coordinate transformation



Projection transformation

ETRS-GK27 ↔ ETRS-TM35FIN

$$N_{ETRS\text{-}TM35FIN} = N_{ETRS\text{-}GK27} \cdot 0.9996$$

$$E_{ETRS\text{-}TM35FIN} = (E_{ETRS\text{-}GK27} - 500\,000\ m) \cdot 0.9996 + 500\,000\ m$$

$$= E_{ETRS\text{-}GK27} \cdot 0.9996 + 200\ m$$

ja

$$N_{ETRS\text{-}GK27} = N_{ETRS\text{-}TM35FIN} / 0.9996$$

$$E_{ETRS\text{-}GK27} = (E_{ETRS\text{-}TM35FIN} - 200\ m) / 0.9996$$

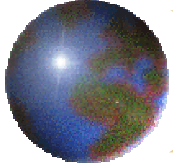
Accurate 2D-transformation between *kkj - and ETRS-TM35FIN – systems*

The purpose is to reduce the realisation errors of the old kkj-system.

Method:

- Affine transformation by triangles

(The Finite Element Method, FEM, with squares was rejected because of more difficulties in later updating)

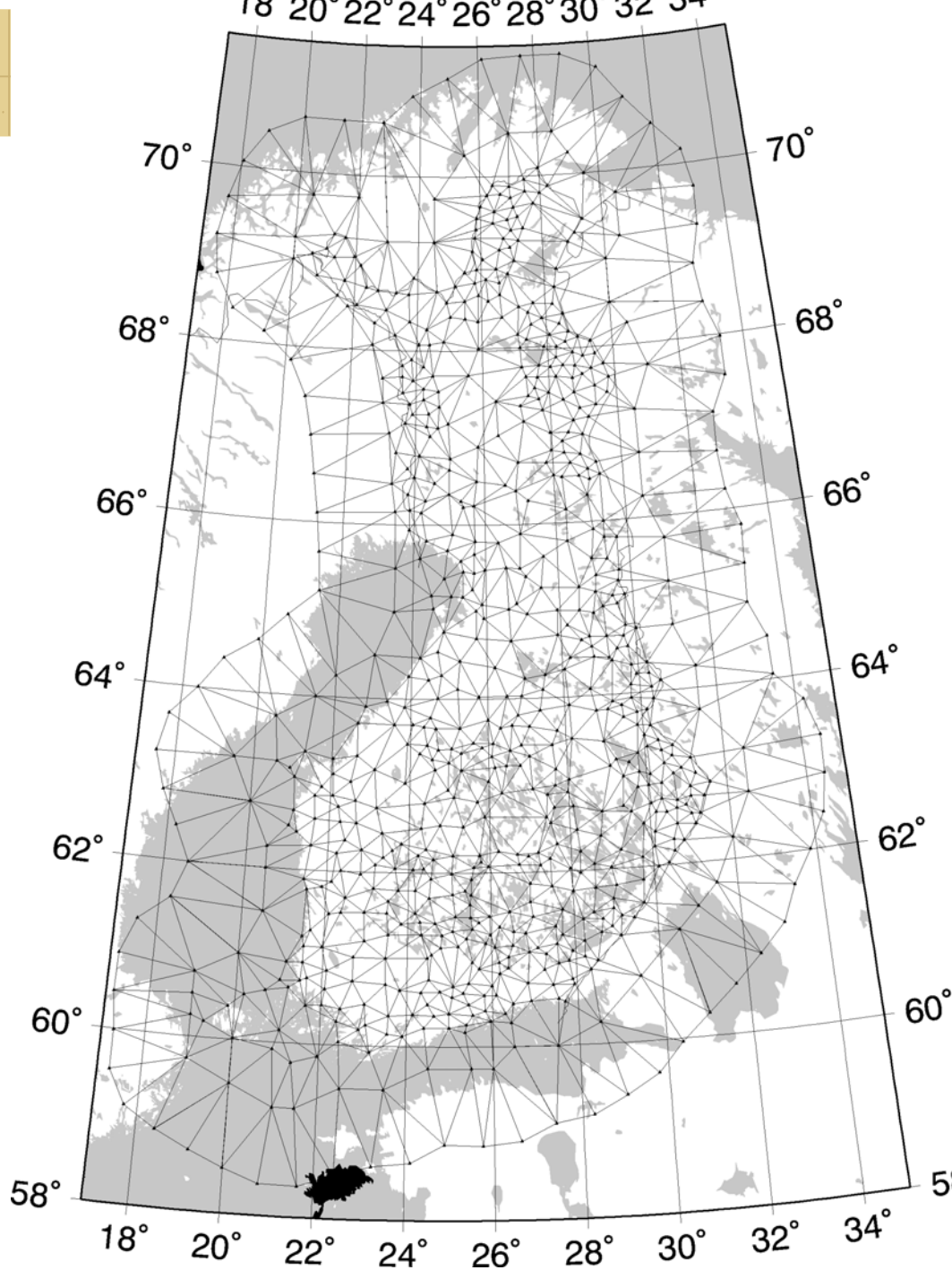


Affine transformation by triangles

$$x_2 = \Delta x + a_1 x_1 + a_2 y_1$$

$$y_2 = \Delta y + b_1 x_1 + b_2 y_1$$

The triangle net of transformation points



Transformation points

- about 600 points with known EUREF- and kkj-coordinates (The Finnish Geodetic Institute)
- More than 100 virtual points outside the country
- The closest virtual points are defined by plane Helmert-transformation and the rest by 7-parameter 3D-transformation (JHS 153)

The strategy of Ministry of Agriculture 2001-2010 contains the following goals

1. The national EUREF-FIN control points (450 pc.) and the accurate transformation formulas between the systems must be in use latest in the end of 2003.
2. Geographic information (map data) must be available in EUREF-FIN coordinate system before the end of 2004.

The strategy of Ministry of Agriculture 2001-2010 contains the following goals

3. Topographic maps have to be available (printed) also in UTM-projection before the end of 2005.
4. The new vertical reference system based on the 3rd precise levelling and joined with the European vertical reference system must be realised by the end of 2006.