Hochschule Karlsruhe - Technik und Wirtschaft   University of Applied Sciences

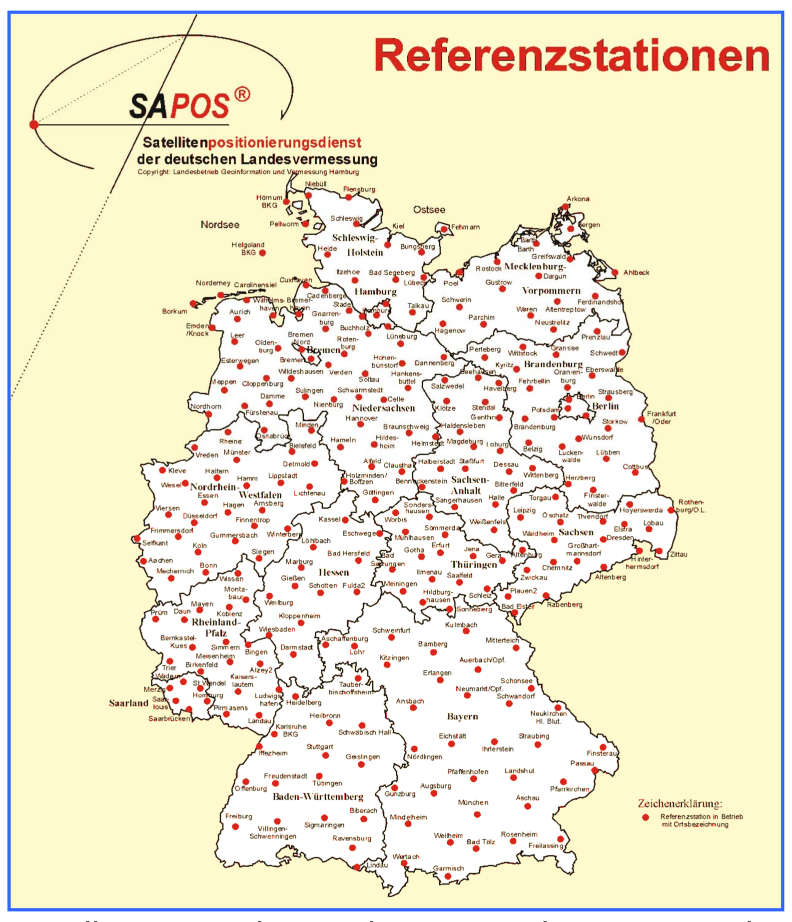
Faculty of Geomatics

Deformation Integrity Monitoring for GNSS-Positioning Services Including a Scalable Hazard Monitoring by the Karlsruhe Approach (MONIKA)

Reiner Jäger, Peter Spohn

Demands for Deformation Monitoring

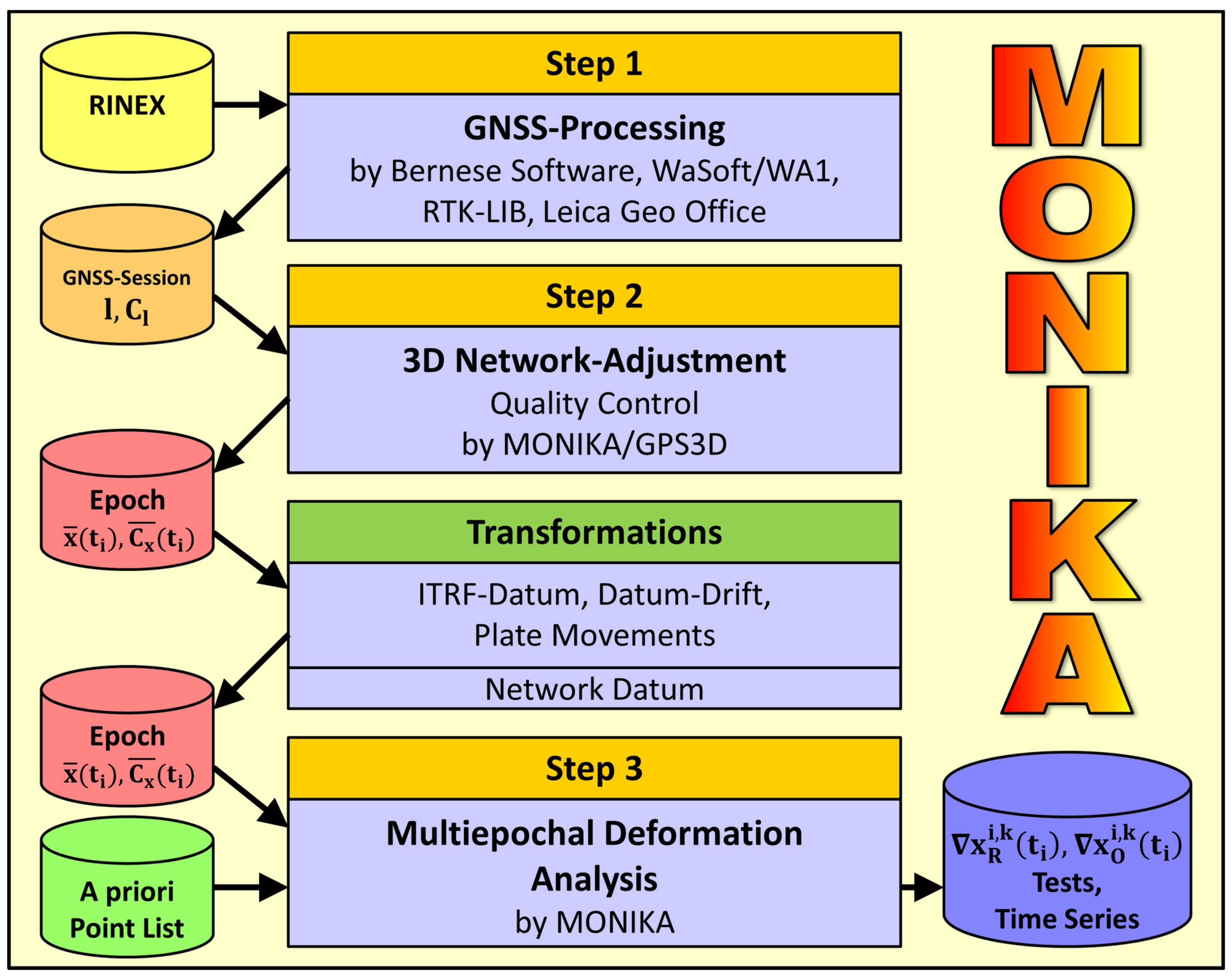
The capacity of an absolute positioning in a GNSS-positioning service network demands, that possible changes of the coordinates of the reference stations in the amount of a few millimetres are detected ad hoc. The reason for position changes of GNSS-reference-stations reaches from geological movements, over deformation due to mining, changes in the ground-water level, to local deformations of the building carrying the GNSS-antenna.



The development of GNSS-reference station coordinate monitoring (MONItoring by the KArlsruhe approach - MONIKA) is being carried out in the frame as research project at the Institute of Applied Research (IAF) an the Faculty of Information-Management and Media of the Karlsruhe University of Applied Sciences (www.monika.ag). The Department for Geodesy and SAPOS of the state survey agency of Baden-Württemberg, Germany, is also involved as a cooperation partner. The MONIKA deformation integrity approach is based on epoch state information of the coordinates and covariance matrices at epoch time t. As concerns the network design, MONIKA is both multivariate and multi-epochal.

Coordinate-related Deformation Analysis

The MONIKA-concept is a coordinate-based deformation analysis concept which consists of three steps. In the first phase, GNSS RINEX files as original observations are processed, or, alternatively, SINEX-files can be used. The second phase comprises the adjustment of the epochs or epoch durations, which is followed by the third phase, namely the deformation analysis.



MONIKA Step 1

GNSS RINEX-Data

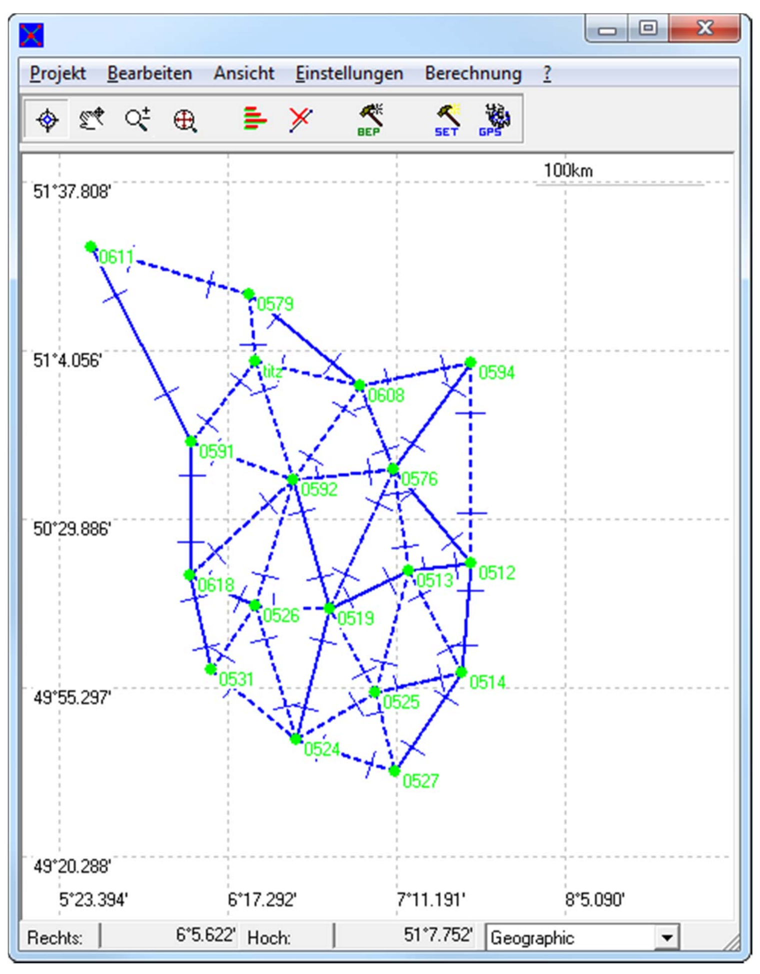
GNSS-Processing

GOCA-GNSS-Control

$l(t_i), C_l(t_i)$

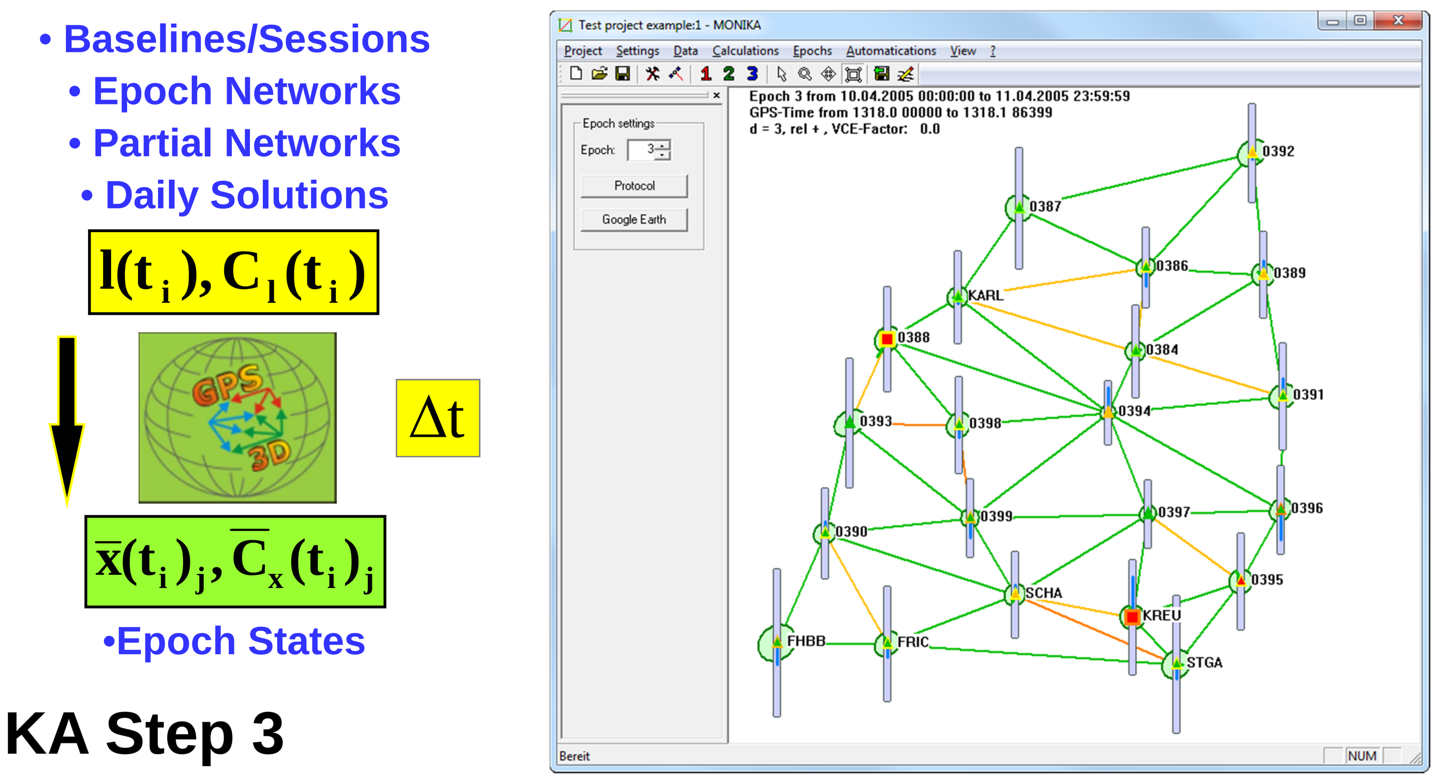
To be automatically controlled by GOCA-GNSS-Control
- WA1 (Wanninger Software)
- RTK-LIB

Supported by Interface
- Bernese GPS-Software 5.0
- WaSoft (Wanninger Software)
- LGO, Leica GeoOffice



MONIKA Step 2

MONIKA step 2 comprises at first the reduction of the standard trends for the main plates (e.g. the Eurasian Plate), which are parameterised by the IERS, with respect to a defined reference epoch. This is necessary in case of an extended network size and/or an extended time window in the deformation analysis (MONIKA step 3). The second part of computations are due to the datum-transformation of the epoch states of step 1, with respect to the datum set by the approximate coordinates of the coordinate-based deformation analysis (MONIKA step 3).



MONIKA Step 3

The coordinate-based deformation analysis is carried out applying the epoch-related coordinates that are derived from the processing of raw GNSS data and the adjustment of the particular epochs or epoch durations. The basic model of the deformation analysis is the assumption of the congruency of the GNSS network over all epochs, considering (by step 2) the geodynamic trends, e.g. plate movements, within the deformation analysis time window. The functional and stochastic model of the coordinate-related deformation analysis is as the follows:

$$\mathbf{x}(t_i) + \mathbf{v}_{x(t_i)} = \mathbf{D}_R^i \cdot d\hat{\mathbf{x}}_r + \mathbf{D}_O^i \cdot d\hat{\mathbf{x}}_O^i + \mathbf{x}_0^i$$ with the covariance matrix $\mathbf{C}_x(t_i)$

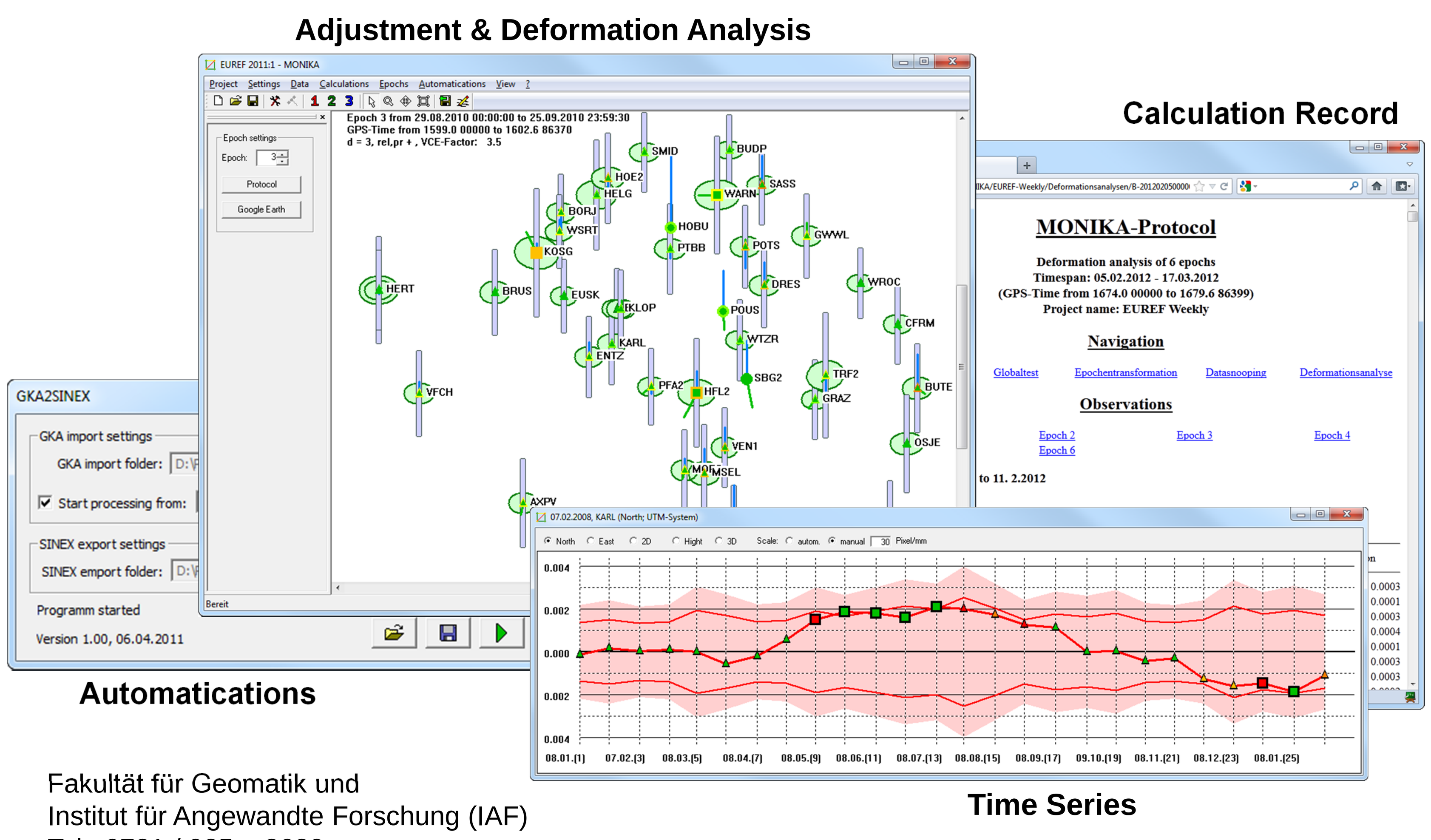
The final epoch states are used as observations including the stochastic model in the coordinate-related deformation analysis. The Gauss-Markov-Model includes all epochs (i = 1,m) within the total duration of the deformation analysis. With null hypothesis of the congruency, the coordinate-related monitoring concept MONIKA means the introduction of the assumed non-deformed parts of the GNSS-reference station network in the i-th epoch. They are the so-called reference points with same coordinates in all epochs. Points, which are a-priori assumed to be moving, and those, which show significant displacements during the testing procedure receive time-dependent coordinates. In terms of deformation analysis they are called object points, denoting them by O in the subscript in the above formula, while subscript R refers to the reference points. The test strategy for the detection of in-congruencies leads to an extended Gauss-Markov-Model by means of a three-dimensional significance test for the estimated displacements.

$$(\mathbf{x}(t_i) - \mathbf{x}_0^i) + \mathbf{v}'_{x(t_i)} = \mathbf{D}_R^i \cdot d\hat{\mathbf{x}}'_R + \mathbf{D}_O^i \cdot d\hat{\mathbf{x}}'^{i}_O + \mathbf{B}_i^k \cdot \hat{\nabla}\mathbf{x}_R^{i,k}(t_i)$$ **Extended GMM**

$$\mathbf{B}_i^k \cdot \hat{\nabla}\mathbf{x}_R^{i,k}(t_i) = \begin{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \cdots \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdots \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \end{bmatrix}^T \cdot \hat{\nabla}\mathbf{x}_R^{i,k}(t_i)$$

$$\hat{\nabla}\mathbf{x}_R^{i,k}(t_i) = -(\mathbf{B}_i^{k^T}\mathbf{P}^i\mathbf{Q}_{vv}^i\mathbf{P}_i\mathbf{B}_i^k)^{-1} \cdot \mathbf{B}_i^{k^T}\mathbf{P}^i \cdot \mathbf{v}_{x(t_i)}$$ and $$\mathbf{Q}_{\hat{\nabla}\hat{\nabla}_R}^{i,k}(t_i) = (\mathbf{B}_i^{k^T}\mathbf{P}^i\mathbf{Q}_{vv}^i\mathbf{P}_i\mathbf{B}_i^k)^{-1}$$

Application Development – Software MONIKA



Project-Leader: Prof. Dr.-Ing. Reiner Jäger. Scientific Assistant: Dipl.-Ing.(FH) Peter Spohn
Hochschule Karlsruhe Technik und Wirtschaft – University of Applied Sciences
Moltkestrasse 30 76133 Karlsruhe, Germany
Web: www.monika.ag and www.goca.info. Email: reiner.jaeger@goca.info

Fakultät für Geomatik und
Institut für Angewandte Forschung (IAF)
Tel.: 0721 / 925 – 2620
Fax.: 0721 / 925 - 2597