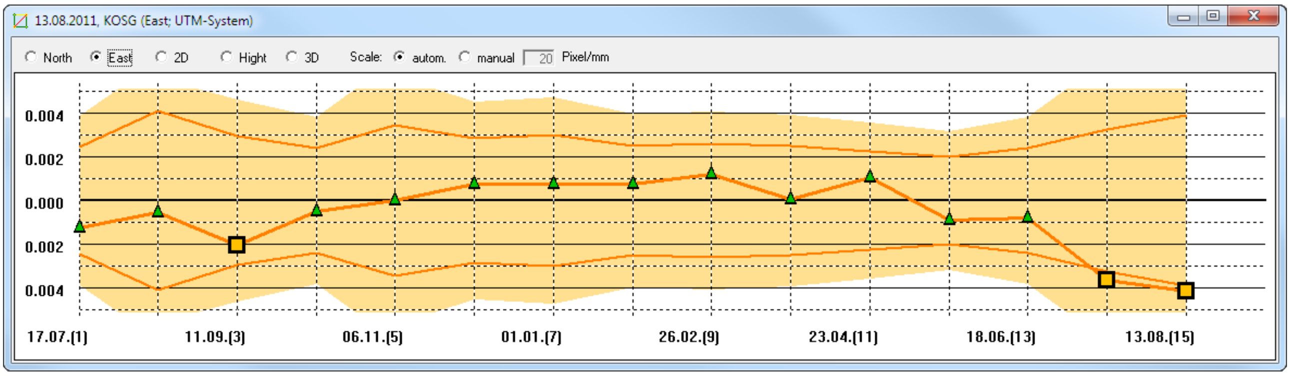
Hochschule Karlsruhe
Technik und Wirtschaft

UNIVERSITY OF APPLIED SCIENCES

MONIKA



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

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Monika Version 3.0

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Introduction

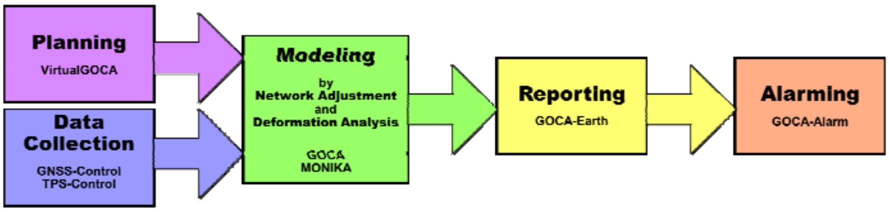

Figure 1: General scheme of an automatic geo-monitoring system

Due to a worldwide development of GNSS-Positioning services, like ***SAPOS*** and *ascos* in Germany for example, these services increasingly play the role of an interdisciplinary application for accurate or highly accurate geo-referencing. Along with the positioning of their clients, providers guarantee for the accuracy of their coordinates. As a result, even the slightest changes of a reference station's coordinates must be detected so that the coordinates can be corrected. This should also be a standard for the networked use of GNSS-reference services. In 2006 the working group "Arbeitsgemeinschaft der Vermessungsverwaltungen (AdV)" therefore decided to monitor these nets, their coordinates and their deformations.

MONIKA puts these requirements into practice with the help of a two-step coordinate-related, multi-epochal deformation-analysis. Furthermore MONIKA can also handle epochs which consist of different reference points. Besides the possibillity to analyse the reference stations in post processing manually, deformation-analyses can also be calculated automatically in near online, including tectonic plate rotations.

The Application MONIKA

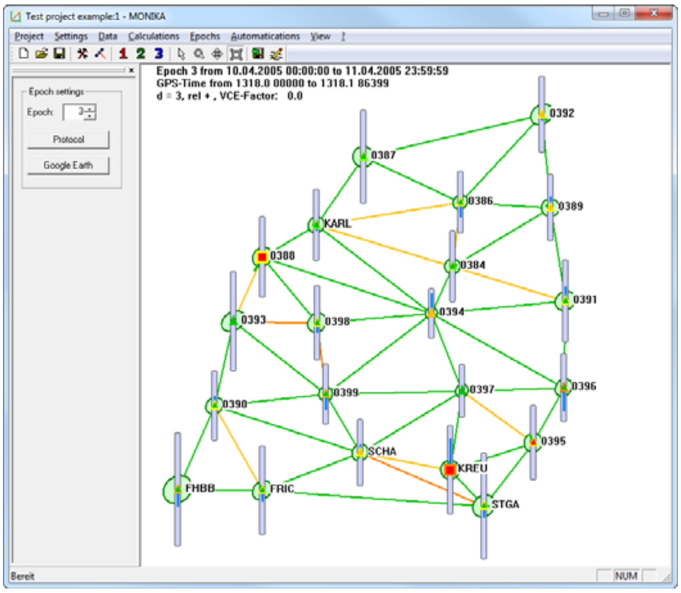

Figure 2: Screenshot of MONIKA V3.0

The C++-based application MONIKA has been created as a single-document-interface (SDI) with the help of Microsoft Visual C++ 2010. The MONIKA software is developed in a object-orientated way. So extensions and improvements can be implemented in MONIKA rather easily.

The application itself is very similar to other windows-based software (see fig. 2). All general functions can be accessed in a drop-down menu quickly. Functions referring to points or epochs, however, can be found in a context menu. Once the 3D-adjustment has been calculated, the points in the reference network are graphically visualized within the display area. Important solutions are highlighted in adjusable different colours. And after the deformation-analysis you can furthermore chose to view the results either as a precise HTML-protocol, a comparable point-list or a time-series diagram (see fig. 3).

The process steps within MONIKA are similar to the steps taken in the mathematical model. First, the GNSS-raw-data has to be processed to baselines or sessions by external baseline processors such as "WA1" from Wanninger Software or by external GNSS-applications such as the Bernese-Software. With this RINEX or SINEX data the epochs are then defined, whereas both data types as well as relative and absolute observations can be mixed and handled. If any errors are statistically detected, the affected observation can be deactivated. Then, the 3D-adjustment has to be repeated, of course. In case of large timespans, a transformation must be calculated with the help of a tectonic palte rotation model. And in case of free network data, the datum and S-transformations are done automatically, during the last step of the main deformation-analysis.

Because of its open baseline- (*.bls, *.gka) and epoch-interfaces (*.epinfo, *.epkoo, *.epkov), MONIKA features many other advantages. Theoretically, you use data from other applications (as long as all required data is available) and import them either before the second or third step of MONIKA's procedure.
All steps can also be predefined in automatic process settings to calculate the epoch adjustment and the deformation analysis online. And with the GOCA-GNSS-Control and GOCA-Alarm module, the whole online geomonitoring chain is supported (see fig. 1)..

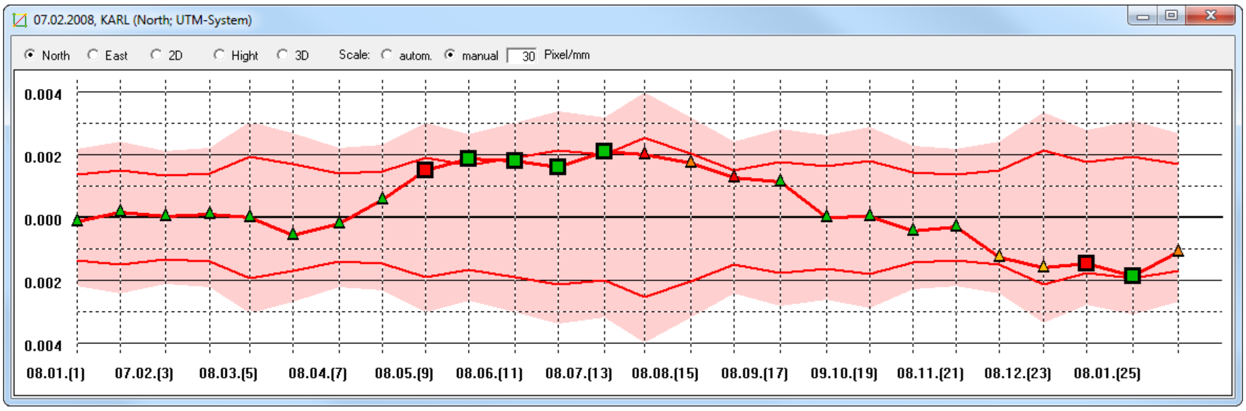

Figure 3: Timeseries from MONIKA V3.0

Mathematical Model

Based on the original GNSS-Observations, the RINEX-Data has to be processed in a first step via DGPS either to non-correlated baselines or to complete network sessions. These baselines or sessions have to be combined to epoch definitions before the next step. In the second step, the 3D-adjustment-software GPS3D calculates epochs from these epoch definitions by using a strict 3D-adjustment, including extensive statistical tests. Depending on the timespan of the deformation-analysis, the tectonic plate movement can't be ignored and has to be taken into account. Furthermore, in the case of free networks, these epochs have to be unified to a comparable datum via a datum- and S-transformation, before they can be summarized in a multi-epochal deformation-analysis (see F1). In this deformation-analysis the Gauss-Markov-Model is extended with displacement parameters (see F2) so that these reference points can be iteratively tested for deformations. If significant deformations are found, these points are changed to object points.

$$\begin{bmatrix} \mathbf{l}_{\text{Ref, Ep 1}} \\ \mathbf{l}_{\text{Obj, Ep 1}} \\ \mathbf{l}_{\text{Ref, Ep 2}} \\ \mathbf{l}_{\text{Obj, Ep 2}} \\ \mathbf{l}_{\text{Ref, Ep 3}} \\ \mathbf{l}_{\text{Obj, Ep 3}} \end{bmatrix} + \begin{bmatrix} \mathbf{v}_{\text{Ref, Ep 1}} \\ \mathbf{v}_{\text{Obj, Ep 1}} \\ \mathbf{v}_{\text{Ref, Ep 2}} \\ \mathbf{v}_{\text{Obj, Ep 2}} \\ \mathbf{v}_{\text{Ref, Ep 3}} \\ \mathbf{v}_{\text{Obj, Ep 3}} \end{bmatrix} = \begin{bmatrix} \mathbf{A}_{\text{Ref, Ep 1}} & 0 & 0 & 0 \\ 0 & \mathbf{I}_{\text{Obj, Ep 1}} & 0 & 0 \\ \mathbf{A}_{\text{Ref, Ep 2}} & 0 & 0 & 0 \\ 0 & 0 & \mathbf{I}_{\text{Obj, Ep 2}} & 0 \\ \mathbf{A}_{\text{Ref, Ep 3}} & 0 & 0 & 0 \\ 0 & 0 & 0 & \mathbf{I}_{\text{Obj, Ep 3}} \end{bmatrix} \cdot \begin{bmatrix} \hat{\mathbf{x}}_{\text{Ref,Def}} \\ \hat{\mathbf{x}}_{\text{Obj, Ep 1}} \\ \hat{\mathbf{x}}_{\text{Obj, Ep 2}} \\ \hat{\mathbf{x}}_{\text{Obj, Ep 3}} \end{bmatrix}$$

F1: Functional model of the deformation-analysis-adjustment based on the Karlsruher Approach for three epochs.

$$\mathbf{l} + \mathbf{v}' = \mathbf{A} \cdot \hat{\mathbf{x}}' + \mathbf{B}_{\text{i}(\text{Ep}_k)} \cdot \nabla \mathbf{x}_{\text{i}(\text{Ep}_k)}$$

F2: Extension of the Gauss-Markov-Model with displacement parameters for the reference point i within epoch k.

In addition to this deformation-analysis, the epochs are also statistically tested and the confidence and sensitive areas for all reference reference points are calculated.

MONIKA Project Examples

The initial MONIKA project did take place in 2006, with the cooperation of the offical regional office for geodesy of Baden-Württemberg. In this project all SAPOS reference stations from France, Swiss, Bavaria, Hesse and Rhineland-Palatinate are still combined, after a preprocessing with the Berner Software 5.0, in an online multi epochal deformation analysis processing. The sensitivity of the single-point-list is outstanding. Based on 24-hour observations we are able to detect movements high significantly around 1,5 to 2,0 mm in horizontal directions and 7 to 10 mm height in several times. And this at an average baseline length of 60 km and a reference-net area of more than 35000 km².

A similar project we have with the offical regional office for geodesy of Rhineland-Palatinate. Apart from an online SAPOS reference station monitoring, they also observe and analyse with the MONIKA software volcano activities of the Eifel-Plume.

Iterative analyses are also done in the frame of the EUREF network by the University of Karlsruhe. The sensitivity of the is there around 2,0 to 2,5 mm in horizontal directions and 6 to 10 mm height, too. Weekly solutions can be downloaded and viewed with the MONIKA-Demo version from www.monika.ag .

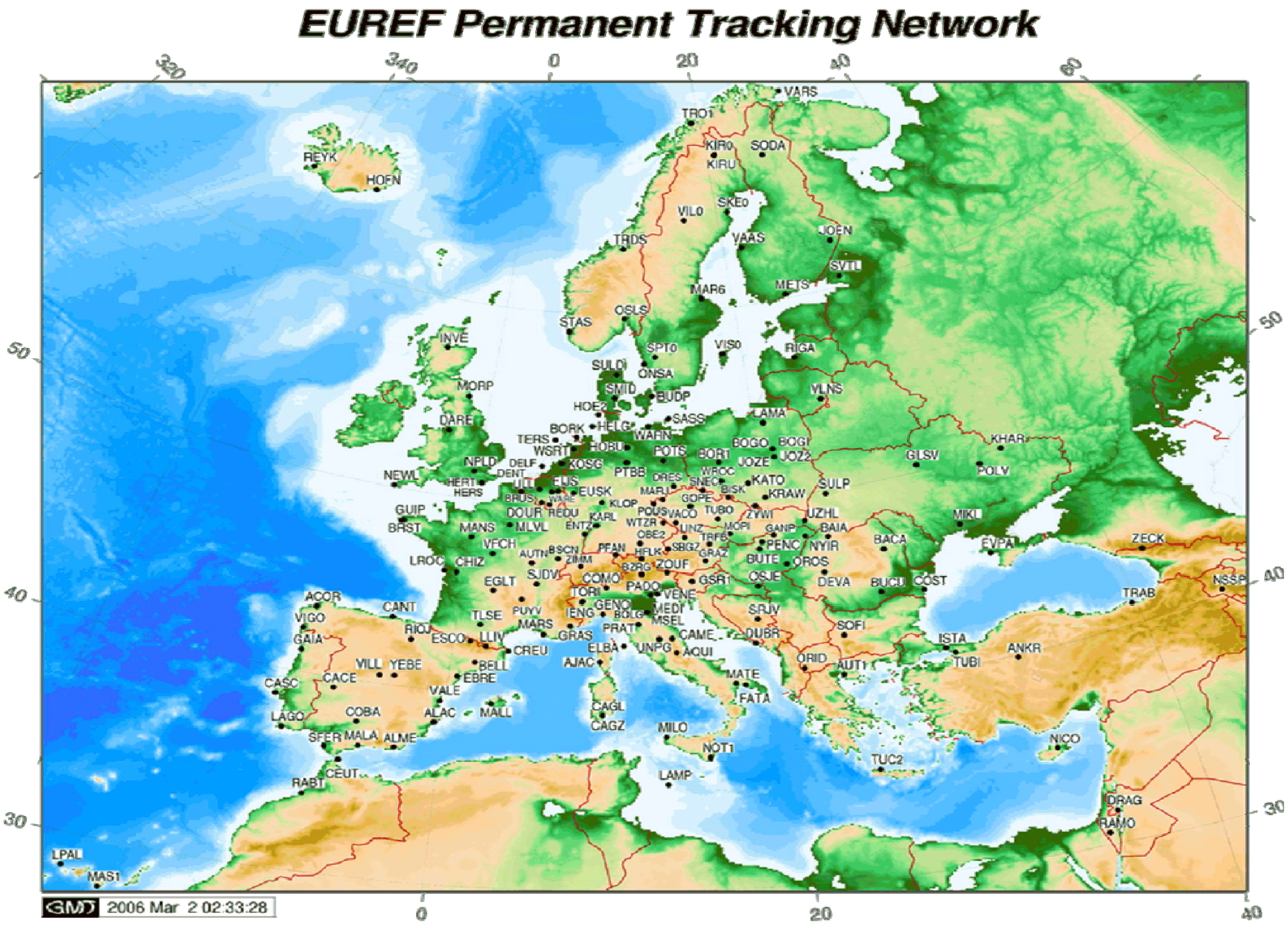

Figure 4: Overview of the EUREF Permanent Tracking Network

Contact (GOCA und MONIKA Project management)

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