ADOPTING GGMATLAB FOR ANALYSIS AND VISUALISATION OF THE BERNESE GPS SOFTWARE OUTPUT

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Abstract. Output of Bernese GPS Software for repeatable (i.e.: geodynamic) GPS surveys contains both movement and accuracy parameters. The GGMatlab modules, created for GAMIT/GLOBK (MiT), implement the movement visualization and trend analysis. This work presents the concept and usage of GGMatlab for Bernese GPS Software. It describes the data conversion procedures and provides several trend analysis examples.

Key words: velocity visualisation, trend models of movement, data conversion

1. INTRODUCTION

A precise geodynamical positioning can only be achieved using appropriate measurement techniques (i.e. GPS, gravimetrics) and advanced computation tools. Bernese GPS Software is the most popular package for this purpose in Europe. It can be used both for determining positions and, in long lasting campaigns, velocities. Although the package writes its output (i.e.: coordinates, RMS, velocities) into a cleanly structured text file, bare digits (no matter how well ordered) will never become more communicative than their visualisation. Unfortunately Bernese GPS Software does not do visualisation and the feature must be sought for elsewhere. A suitable tool for this purpose is (Matlab® -based) GGMatlab[1] written for GAMIT\GLOBK Analysis Software (MIT). GGMatlab holds two independent programs:
- **velview** – for velocity (of a point) visualisation.
- **tsview** – for time series visualisation and analysis.

In order to visualise a Bernese GPS Software output, the output needs to be converted into the format expected by GGMatlab. To do so, one must cross-match the GGMatlab input against the Bernese output.

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2. DETERMINING THE GGMATLAB INPUT FORMAT

GGMatlab supports two file formats for input, one for velview and one for tsview.

2.1. Velview file format

There are no filename requirements except the extension, which must be *.vel. The format implies two lines of heading: one for the column names, second for the reference units. The lines that follow are data and that data is arranged into the following columns:
1.   latitude (decimal)
2.   longitude (decimal).
3.   Eastbound velocity component
4.   Northbound velocity component.
5.   Eastbound velocity adjustment
6.   Northbound velocity adjustments.
7.   RMS (1)
8.   RMS (2)
9.   RHO (the correlation factor between E and N velocity components).
        … The remaining columns hold analogous data for the height component.
The Last column is reserved for station names.

Example of file below (Fig. 1).

Fig. 1. velview file example
Rys. 1. Format pliku velview

2.2. tsview file format

tsview requres three input files named as follows:

- mb_*<STNM>*_*<SOL>*.dat1,
- mb_*<STNM>*_*<SOL>*.dat2,
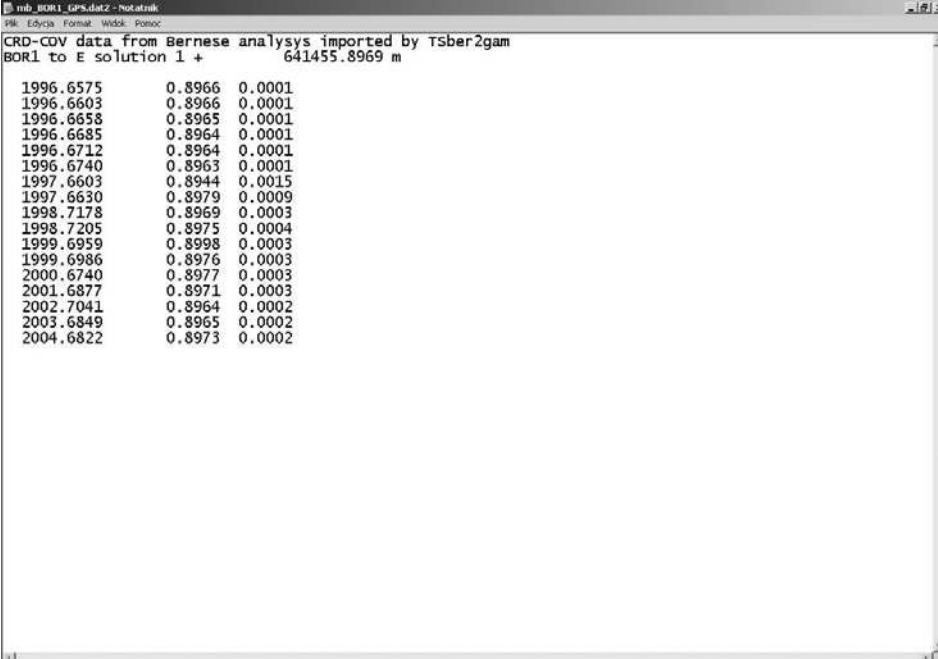- mb_*<STNM>*_*<SOL>*.dat3,

Where *<STNM>* denotes the name of the measured point and *<SOL>* identifies to the measurement method (usually GPS). There are three input files each devoted to a different spatial component:

- *.dat1 is for north
- *.dat2 is for east
- *.dat3 is for the height component.

Every file contains exactly 2 lines of heading. The first is the name of the application that has produced the output. The second identifies the spatial component the file pertains to (one of: X,Y,Z) as well as states its mean value and mean integer value. Data rows follow the heading lines. The data is divided among the following columns:

- Measurement year (decimal).
- Value of the respective coordinate component (reduced by the aforementioned integer mean).
- RMS.

       Example of file below (Fig. 2).

Fig. 2. tsview file example
Rys. 2. Format pliku tsview

3. BER2GAM CONVERSION SOFTWARE. FILE READING
AND GATHERING DATA

As mentioned before the output from Bernese GPS Software is clean and well structured, i.e.: data are sorted by category and stored in independent sections. Point position components are collated in one block with their RMS, and similarly, velocities and their RMS are stored in different data block. Of course, the extraction of the time series (velview) will take longer proportionally to number of files taken for conversion. The Bernese GPS Software example output is shown below (Fig. 3).

Fig. 3. Bernese output file
Rys. 3. Plik wynikowy Bernese

4. DATA VALIDATION AND PREPARE FOR WRITE

The next stage of conversion is data validation. For the velocity data it is simple comparison between the number of stations found in the velocity data block and coordinate data block. Data validation for time series is slightly more complicated. The first step is acquiring the measurement epoch. By convention the epoch is embedded into the file name, failing that (file renamed), the epoch can be read from the file body.

The second step of the data validation is determining the number of available samples. If there are not enough epochs (at least 5) [2] for a given point, the point is ignored. The last stage of the validation is, for each given point, removing redundant measurement entries (i.e.: two or more from the same day) and sorting them against the timestamp.

5. GGMATLAB ANALYSIS

As mentioned before, GGMatlab includes two programs, one for the velocity visualisation, and the other for the time series analysis.

5.1. VELVIEW

Velocities and directions expressed numerically (in a text file) do not offer much of a readable view of the geodynamics found in a given area. It is perhaps feasible to draw conclusions from up to four data samples, above that however; one needs some sort of visualisation tool e.g.: velview.

In principle, velview produces a velocity vector field, i.e.: graphical vectors depicting the velocity value, direction and RMS (at head of arrow). The vectors are scaled (the legend below the drawing indicates the scale). In addition to the velocity field, it is also possible to add more data to the visualisation:
- Secondary velocity field (from subsequent years).
- Linear objects – rivers, borders, faults etc.
- Point objects – cities, earthquakes, etc.

This data can be imported from auxiliary files. The data must include B, L coordinates and may include additional data (i.e. earthquake magnitudes)

The velview's GUI (Graphical User Interface) has the *Load Options* panel featuring:
- SigLimit - limits velocity uncertainties.
- Error Scaling – custom multiplier of the original (input) sigmas.
- Confidence Int - changes the confidence intervals for the error ellipses and vertical velocity error bars.
- Arrow Length – scaling the vector lengths relative to the screen size (millimetre vector value produces a millimetre long vector on the screen).
- Arrow Head Size – scaling of the arrow head.
- Display – sets the contents of the figure: Three checkboxes:
  - N – Toggle site names.
  - H – Toggle horizontal velocities.
  - V – Toggle vertical velocities.

The GUI also includes:
- Pan Buttons – these four buttons pan the view by half the width or height respectively.
- Zoom Buttons – there are two kind of zoom buttons:
- The first acts like the normal Matlab® zoom.
- The second, Vec Zoom In and Vec Zoom Out preserves the vector lengths.
- Redraw Button – redraws the plot with the current options.
- Profile Buttons – velview allows evaluating and drawing terrain profiles. There are two ways of picking a new profile line:
  - By typing the azimuth of the profile line.
  - By actually drawing the line on the plot.

When the profile line is in place, one needs to choose the area for the new profile to cover. The stations included by the area will be tagged with yellow circles. Promptly thereafter the second plot window opens showing the profile line and selected stations. There are several options for this plot. These are:

- o   Point identification.
- o   Point deletion.
- o   Function fit.
- o   Save.
- Offset row – removes the offset between the primary and secondary velocity fields.
- Alignment row – computes the offsets between the primary and secondary velocity fields.
- RmDups – removes duplicate site names.
- Stats – computes the velocity differences between the nearby points in the current view.

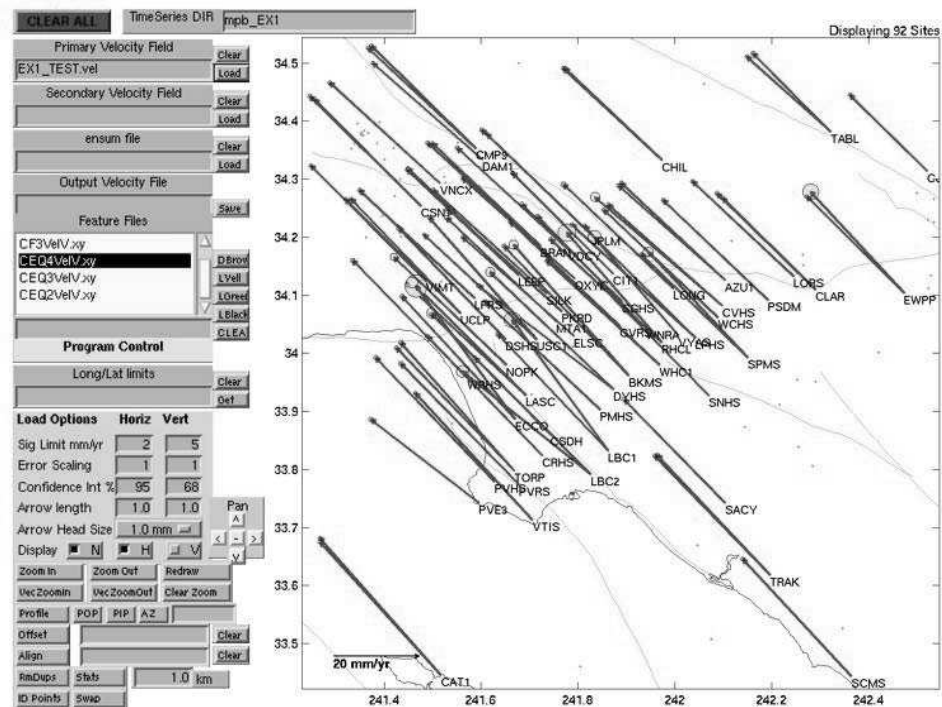Velocity field and profile line examples are presented on Figures 4 and 5.

Fig. 4. velview visualisation example
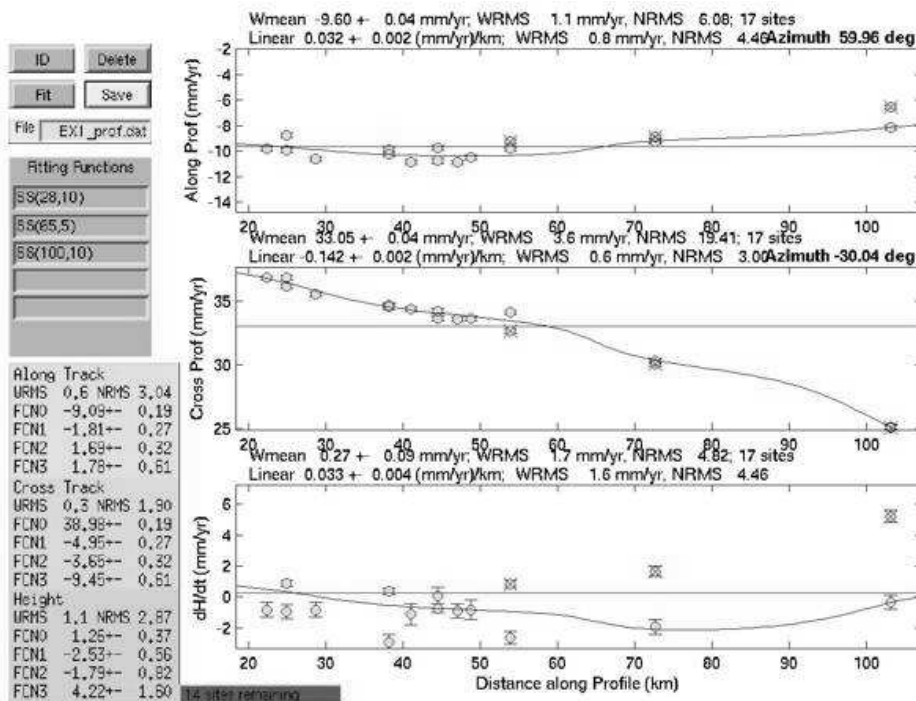Rys. 4. Przykład wizualizacji velview

Fig. 5. Profile line visualisation example
Rys. 5. Przykład wykresu profili

5.2. tsview

For each point, tsview will draw three separate plots (one per a coordinate component). Each plot depicts the location versus time. Each point can be further analysed in respect to its (movement) trend. The result depends on the selected options:

- Type of the detrend function with the following available:
  - o Logarithmic.
  - o Exponent.
  - o Sine (Annual & Semi-annual).
  - o Cosine (Annual & Semi-annual).
- Linear only resid – when this check-box is checked, the estimated sine and cosine, exponent and logarithm coefficients are not removed from the data.
- Real sigma – when chosen, the algorithm assumes that the noise process is the first order Gauss Markov process. The time series residuals to the fit to the data are averaged over increasingly longer intervals.
- Automatic outlier rejection – removes outliers that do not satisfy the given criterion.
- Error rejection – rejects/ignores high RMS rate entries.
- Append breakpoints – a breakpoint marks the time of an event (i.e. an earthquake or displacement). Given an appropriate configuration, breakpoints can be used to recalculate the trend characteristics starting from specific events.

The remaining tsview options bear no influence on the detrend process. They allow appending auxiliary data and modify the view or data that is being displayed. These options are:

- Average – displays the average of time series residuals over the given interval (in days).
- Append data from an additional station.
- Zoom in and out of the selected area of the plot.
- Watch the selected time span.
- Save detrend results.
- Print the detrend plot and results.

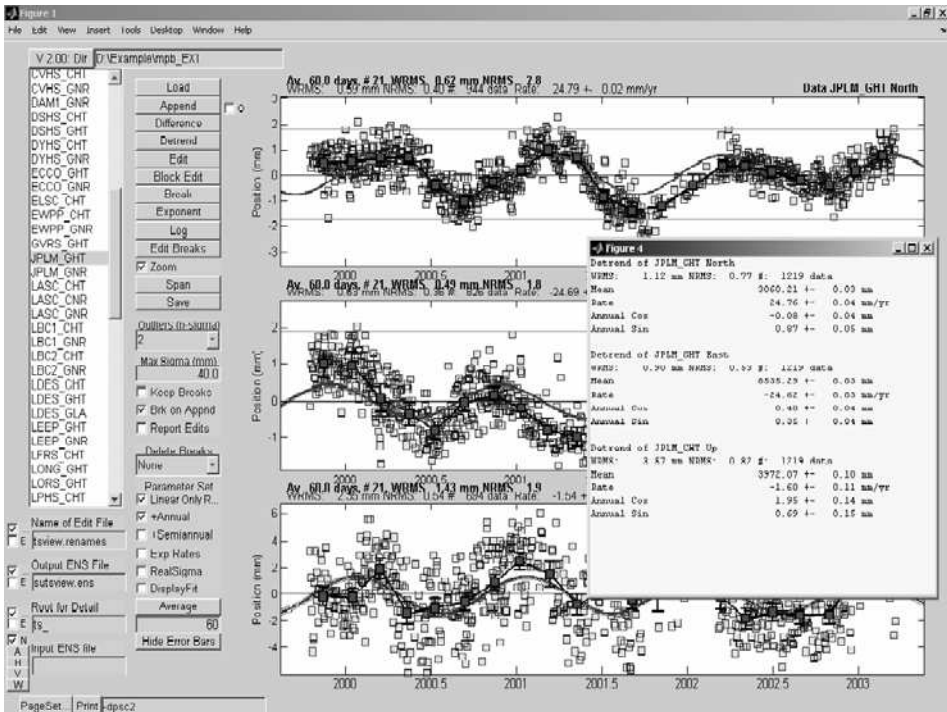Examples of a trend line including numerical results are presented on Figure 6.

Fig. 6. Example of tsview analysys
Rys. 6. Przykład analizy tsview

6. CONCLUSIONS

Since there is no visualisation and analysis tool specifically tailored for Bernese GPS Software, it has been difficult to present and process its output. This paper proves that with a negligible effort of writing a simple data converter, Bernese can gain a new, powerful visualisation and analysis tool. What is also important, both GGMAtlab and ber2gam are open source tools and hence can be modified for individual purposes. GGMatlab can be downloaded from the GAMIT/GLOBK website – http://www-gpsg.mit.edu/~tah/GGMatlab/.

Ber2Gam has been implemented based on MATLAB ® (licence no.: 101979), within the processing time grant awarded by Wroclaw Centre for Networking and Supercomputing.

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ZASTOSOWANIE MODUŁÓW PROGRAMOWYCH GGMATLAB DO WIZUALIZACJI I ANALIZ WYNIKÓW OPRACOWANIA SIECI GPS ZA POMOCĄ BERNESE GPS SOFTWARE

Streszczenie: Pliki wynikowe programu Bernese GPS Software z obliczeń z wielu epok pomiarowych GPS zawierają parametry ruchu oraz ich dokładności. Moduły GGMatlab, napisane dla środowiska GAMIT/GLOBK (MiT), mają możliwość wizualizacji ruchu oraz analizy trendu. Praca ta prezentuje możliwości wykorzystania modułów GGMatlab dla wyników uzyskanych ze środowiska Bernese. Przedstawiono także algorytm konwersji danych oraz przytoczono przykłady opracowania danych.

Słowa kluczowe: wizualizacja prędkości, modele trendu ruchu, konwersja danych