EPC User's Manual

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Websites

EPC: http://sourceforge.net/projects/epcalc/

Abbreviations

BSD:	Berkeley Software Distributionas
CRG:	Center for Research in Geomatics
EPC:	Euler Pole Calculator
GUI:	Graphical User Interface
JVM:	Java Virtual Machine
OS:	Operating System

1. Introduction

The estimation of Euler pole parameters has always been an important issue in global tectonics and geodynamics studies. In addition, the increasing number of permanent GPS stations and the facility of access to their data, along with advances in computers, promises new methods and tools for the estimation and the quantitative analysis of Euler pole parameters.

The Euler Pole Calculator (EPC) software was developed using a set of mathematical algorithms based on the model of tectonic plate motion on a spherical surface. The software is able to calculate both the expected velocities for any points located on the earth's surface given the relevant Euler pole parameters, and estimate the Euler pole parameters given the observed velocities of a set of sites located on the same tectonic plate.

2. Programming language

EPC has been developed using the MATLAB programming language with Graphical User Interface (GUI). MATLAB has evolved during the last decade, and became increasingly popular in Earth sciences. It not only provides a high number of tested and ready-to-use algorithms for most of the data analysis methods, but allows the existing routines to be modified and expanded, or new software to be developed rapidly. MATLAB was designed to perform mathematical calculations, to analyze and visualize data, and to facilitate the writing of new software programs. MATLAB, on the other hand, is a cross-platform programming language. Many applications developed under MATLAB are portable and can be readily run on Windows, Macintosh, and Unix/Linux operating systems (OS). Moreover, the MATLAB code can be compiled into an executable program, in order to increase the run time speed. These reasons make Matlab a good choice for developing software programs in science and engineering.

3. Installation

EPC is freely available as an open source software under the BSD license. The source code can be downloaded from the EPC website. The package includes a set of MATLAB m-files (functions), fig-files (GUIs), and the user's manual as well as a separate folder for some sample input/output files in different formats.

To install the software, the following steps should be done:

1. Download the package from the EPC website and unpack it. Then, add the EPC main folder to the MATLAB search path (e.g., `addpath <file_address_to_the_epc_folder>`).
2. Check the MATLAB installation to see whether the following toolboxes are already installed: Statistics and Mapping.

   > Since EPC has a GUI, in UNIX like OS's, an X-Window environment should also be installed, and MATLAB should be started with the Java Virtual Machine (JVM) enabled.

3. Type `epc` in the MATLAB command prompt to run the program (Figure 1). The figure shows the input data table, the output data table, the map canvas that include the world map and the

tectonic plates borders as well as the Euler pole parameters, statistics, and the scatter plot for velocities.

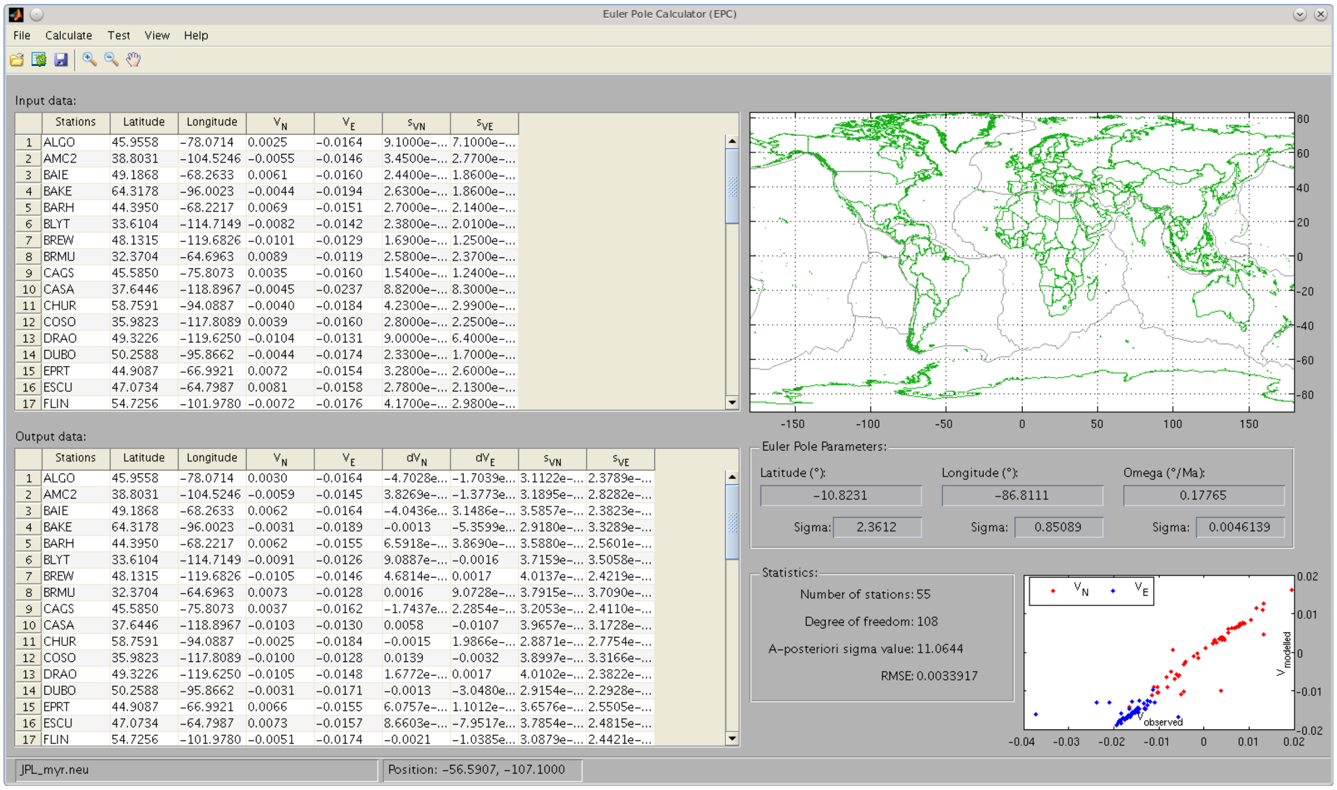

Figure 1: The EPC main window. The upper- and lower-left tables show the imported and the calculated velocities based on parameters of the Euler pole, respectively. The map canvas on the upper-right showing a map of tectonic plates overlaid on the world map gives the user an overview of the place of stations and velocity vectors. The statistical information on lower-right side of the window provides information about the quality of the least-squares adjustment in the inverse Euler pole problem. The regression canvas in the lower-right corner shows the scatter plot of the observed (input) versus the modeled (output) velocities separately for the North and the East components.

4. Calculation

4.1. Input data files

The EPC can be used for calculating the Euler pole parameters of a rigid tectonic plate using a set of velocity vectors, or for calculating the velocity vectors of some points with known coordinates either in the Earth-Centered Earth-Fixed (ECEF) X, Y, Z or the Local Geodetic (LG) North, East, Up Cartesian coordinate system (CCS). Therefore, the software accepts two inputs files in two ASCII text formats: ECEF X, Y, Z and NEU. In the former format, data are stored in 13 space separated columns including: station name (column one), coordinates of the station in the X, Y, and Z directions in ECEF CCS in meters (columns 2-4), associated velocities to the station in the X, Y, and Z directions in meters per year (columns 5-7), and their corresponding velocity errors (one sigma) in meters per year (columns 8-10) as well as the correlations between velocity components (X-Y, X-Z, and Y-Z) (columns 11-13).

```
# Comment 1
# Comment 2 ...
ALGO  918129.452800  -4346071.248100 4561977.837700 -0.016274 -0.001929  0.001428 0.001475635456 0.001432654878 -0.000000010400
AMC2 -1248596.122400 -4819428.226200 3976506.015200 -0.014837  0.000487 -0.004041 0.002484451650 0.003585735629  0.000000008750
ANNE  1667791.735300 -3834672.498400 4799895.210200 -0.016684 -0.001957  0.004206 0.001660572191 0.002227105745 -0.000000055700
ATRI  1403882.126000 -4138421.207100 4630206.894200 -0.016678 -0.002080  0.003176 0.001083974169 0.001436140662 -0.000000008350
BAIE  1546823.378500 -3879765.121400 4804185.032400 -0.016324 -0.001835  0.003749 0.000988685997 0.001245993579 -0.000000008000
BAKE  -289833.886100 -2756501.026300 5725162.197500 -0.019842 -0.001689 -0.001805 0.004301743832 0.006305751343  0.000000000550
```

Figure 2: A sample data file in the ECEF format.

Lines starting with # sign are comment lines and therefore are not read.

In the latter format, data are stored in 8 space separated columns including: station name (columns 1), coordinates of the station in LG CCS in decimal degrees (columns 2-3), associated velocities to the station in North and East directions in meters per year (columns 4-5), and corresponding velocity errors (one sigma) in meters per year (columns 6-7) as well as the correlation between the two velocity components (column 8).

```
# Comment 1
# Comment 2 ...
SHE2 46.220691 -64.552011    0.0068  -0.0151   0.003579106034   0.004257640191  -0.000000092350
SHER 45.401144 -71.898044    0.0045  -0.0160   0.002102974084   0.002457641145  -0.000000038350
SRBK 45.401133 -71.898079    0.0043  -0.0152   0.004732599708   0.005908680056  -0.000000098950
TRIV 46.344026 -72.539312    0.0042  -0.0166   0.000978519290   0.001504160896  -0.000000012750
UNB1 45.950209 -66.641705    0.0068  -0.0156   0.002513961018   0.003867169508  -0.000000060950
UNBJ 45.950210 -66.641706    0.0071  -0.0151   0.002234390297   0.002492990172  -0.000000052000
VALD 48.097057 -77.564167    0.0018  -0.0167   0.001474788120   0.001694107435  -0.000000016100
WES2 42.613336 -71.493327    0.0049  -0.0148   0.001102270384   0.001071214264  -0.000000004600
```

Figure 3: A sample data file in the NEU format.

- Except for the names of the stations, all the data in the ECEF format must be in ECEF CCS, and in the NEU format must be in LG CCS.
- Users can find two sample input data files in the “sample” subdirectory of the software.

You can open a data file in one of the above-mentioned formats using “File ► Open” menu or choose the “Open file ...” icon from the toolbar. Then the data is displayed in the “Input data” table (see Figure 1).

In either of the formats, station names and their coordinates and velocities must be provided. In other words, the software does not accept non-real values such as empty fields for the station coordinates and velocities, but this is acceptable for sigma values. Missed sigma values are substituted by “Not a Number (NaN)”. However, when sigma values are necessary for calculations, for example in the inverse Euler pole problem to form the weight matrix for estimating Euler parameters in the

	least-squares adjustment, they are substituted with the identity matrix. The software does not accept NaNs and real values at the same time.

4.2. Euler pole Calculations

In the direct Euler pole problem, the user should enter Euler pole parameters and their associated sigma values. Then, velocity vectors and velocity residuals along with the estimated velocity errors are calculated, depending on the coordinate system of the input data. To do this, you can choose "Calculate►Velocities" or press the "Velocities" icon in the toolbar.

In the inverse Euler pole problem, Euler pole parameters and the corresponding covariance matrix are estimated based on the coordinate system of the input data without the user intervention. Furthermore, the degree of freedom, a-posteriori sigma, and the RMSE value are calculated in the inverse Euler pole problem. To do this, you can choose "Calculate►Euler pole" or press the "Euler pole" icon in the toolbar.

4.3. Statistical tests

You can use three statistical tests to evaluate the quality of the solution in the Euler pole or velocity vector estimation.

4.3.1. Chi-square test

The X^2-test is used to test the null hypothesis that the velocity residuals are a random sample that can be described by a Gaussian distribution with a typical central value and a random dispersion around it. The null hypothesis is tested against the alternative hypothesis that the velocity residuals are not normally distributed with the estimated mean and variance. In the software, the velocity residuals in East and North directions are separately tested at the 5% significance level, and the result is reported along with the probability of observing the given statistic or one more extreme under assumption of the null hypothesis (the p-value), the chi-square statistic, and the degree of freedom.

4.3.2. Pearson's correlation coefficient

This test is used to give a rough estimate of the rectilinear trend in the results in the form of a scatter plot as well as numerical values. The observed velocities from the input data file are first plotted against the modeled velocities. This scatter plot visualizes the existing trend in the data set and shows the consistency of the results. Since the Pearson's correlation coefficient is very sensitive to disturbances, it helps to detect outliers in the data set. Then, the correlation coefficients in East and North directions are separately calculated. The significance of the correlation coefficient is tested afterward at 5% significance level using the Student's *t*-test. If the calculated *t* is higher than the critical t, the correlation coefficient is significant.

4.3.3. Standardized residuals

This test is very well suited test to find individual blunders in the input data set. In other words, it can be used to exclude sites containing gross errors in their velocities. For two reasons, observations that are detected as blunders should not be all removed in one step: (1) the existence of any blunder in the data set will affect the remaining observations, and (2) the rejection level depends on the σ_0. Therefore, it is recommended to eliminate only the larger blunder(s) from the list of observations.

5. Utilities

You can show or hide location of stations and their names from the input file, as well as the estimated velocity vectors, velocity residuals and the Euler pole location on the map canvas of the software (Figure 4) using the corresponding menu commands of the “View” menu.

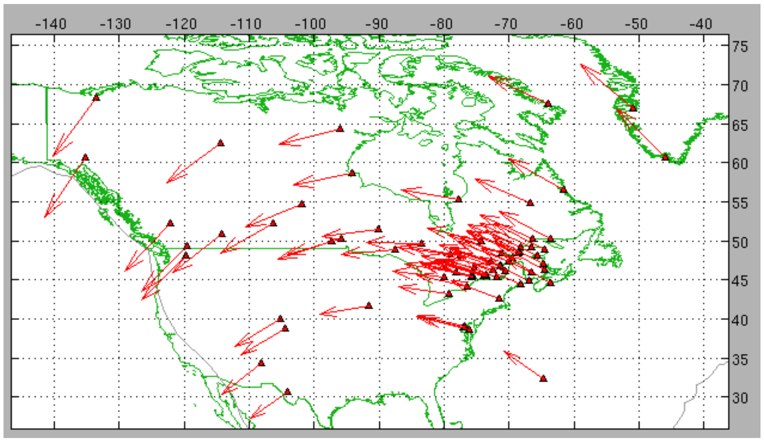

Figure 4: The EPC map canvas showing the position of stations and the associated velocity vectors.

Because of the small size of the map canvas and the need to have the exact numerical values, the estimated parameters can be saved in the comma-separated values (csv), ESRI shape file (shp), and Google Keyhole Markup Language (kml) file formats using the “File ► Save ► Output table...” or “File ► Save ► Euler pole parameters...”. This makes the further numerical or visual analysis of the outputs very easy.