Bayesian Earthquake Dating (BED) v1.0

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We demonstrate how to set up a new case study and to run the BED code, based on the Fiamignano (FIAM) case study. We recommend MATLAB 2016a, or newer, because of the improved compression available for the storage of output files in these versions.

1 Setup

First, create a directory with the name of the case study, e.g., `CaseStudies/FIAM/`, in the `CaseStudies/` directory. The directory must include the data files `rock.txt`, `colluvium.txt`, and `magfield.txt` in the same format required by the code of Schlagenhauf et al. (2010). Next, create a MATLAB file with the same name as the directory, `FIAM.m` and the following minimal structure:

```
function [parameters,prior,settings,truth]=FIAM(parameters,prior,settings)
parameters.H_sc = 2705;    % scarp height along fault (cm)
parameters.H_tr = 115;     % trench depth along fault (cm)
parameters.alpha = 23;     % colluvium wedge dip (degrees)
parameters.beta = 42;      % preserved scarp dip (degrees)
parameters.gamma = 33;     % upper eroded scarp dip (degrees)
parameters.rho_rock = 2.7; % scarp rock mean density (g cm^{-3})
parameters.rho_coll = @(~) UniformProposal(1.2,1.8); % colluvial wedge mean density (g cm^{-3})
prior.d_max = 110;         % maximal displacement (cm)
end
```

2 Run simulations

Next, run the BED code as follows:

```
>> save_interval=60;
>> RunBED('FIAM',save_interval)
```

where `save_interval` specifies how frequently (in minutes) the code saves the results. (Note, however, that the initial offline phase takes around 20 minutes, and the first interval is only started afterwards.) The results are stored in `results.mat` in the case study directory. To terminate a run, press `Ctrl+C`; by default, the code keeps running indefinitely. The resume a terminated run (`results.mat` exists in the case study directory), simply use `>> RunBED('FIAM',save_interval)` again. If changes to the settings of the case study were made, however, `results.mat` must be manually removed first (the command will throw an error otherwise, and refrains from automatic deletion to prevent accidental data loss).

3 Visualize results

To visualize the results, use `>> VisualizeBED('FIAM')`. This command can be run as soon as the output file exists, and if desired in parallel to an ongoing run in a separate MATLAB instance. It shows a wide range of posterior distributions and the Gelman-Rubin MCMC convergence diagnostic. Note that, depending on the number of generated samples, running this command may take multiple minutes. The amount of burn-in (in percent), the time period to visualize (in kyr), the width of confidence intervals, and the time-resolution of plots (when applicable) can be controled in the main window.

To obtain statistically significant plots, the burn-in period should be tuned such that the maximal Potential Scale Reduction Factor (displayed in figure 'Convergence diagnostic') is below 1.1 (the maximum can be read off the plot but is also printed in the terminal). If this is not possible for any value of the burn-in, more simulations are necessary.

In case simulations were done elsewhere, the contents of a `results.mat` file may manually be loaded into MATLAB and visualized using `>> VisualizeBED(results)`.

Remarks

The following default settings and prior parameters can be found in `MCMC/add_defaults.m` and can be changed in the case study file (`CaseStudy/FIAM/FIAM.m`) simply by adding and modifying the corresponding line:

```
prior.recurrence_mean_min = 200; % Average interevent times are drawn from Inverse Gamma distribution
prior.recurrence_mean_max = 2000;% with parameters 'recurrence_mean' and 'recurrence_alpha';
prior.recurrence_alpha_min = 1;  % these parameters are inferred within the ranges given here.
prior.recurrence_alpha_max = 10; % ...
prior.switch_distance_min = 3e3; % Distance between different long-scale slip-activity regions is drawn
prior.switch_distance_max = 3e4; % from exponential distribution with (inferred) mean 'switch_distance'
prior.tau_min = 0.5;             % Minimal short-scale variability of inter-event times
prior.tau_max = 1.5;             % Maximal ...
prior.d_min = 10;                % Minimal displacement (along fault plane)
prior.d_max = 300;               % Maximal displacement (along fault plane)
prior.T_init_min = -20000;       % Lower bound on demise of LGM
prior.T_init_max = -12000;       % Upper bound on demise of LGM
prior.p_zero_freq_max = 0;       % Likelihood of a long-scale activity region with zero activity
prior.no_more_slips = 0;         % Time after which no more earthquakes occured
prior.previous_earthquakes = []; % 2xN array of known earthquake times and displacement sizes
settings.T_min = -30000;         % Start time of simulations
settings.debug = false;          % Display debug information during runs
settings.group_size = 2;         % Number of independent Markov Chains
settings.pt_levels = gamma(linspace(2,2+19/6,20)); % Parallel tempering levels
settings.dT = 50;                % Time discretization in simulations
settings.rho_max = 0.1;          % Model error is inferred between 0 and rho_max
settings.correlation_length_max = 0;  % Correlation length of model error
settings.modelscarp =  @simulateCl36; % Function that simulates Cl36 concentrations
settings.L = 6;                  % Accuracy of sparse grid interpolation in offline phase
settings.thinning = 5; % One out of how many samples should be saved
parameters.Psi_s = @(~) NormalProposal(48.8,1.7);
parameters.Psi_mu = @(~) NormalProposal(190,19);
parameters.Lambda_sp = @(~) UniformProposal(180,220);
parameters.Lambda_mu = @(~) UniformProposal(1300,1700);
```

In particular, to change the ^{36}Cl simulation code, for example to that of Schlagenhauf et. al (2010), add the line `settings.modelscarp = @<alternativeSimulator>` to the case study file.

The variable `truth` that is returned by the case study function can be used to add the truth in case it is known (synthetic test cases). For this purpose, add `truth.jumps = <array of displacements (cm), e.g. [10,30]>` and `truth.times = <array of event times (yr), e.g. [-1e4,-1e3]>`.

The settings of the offline phase of our ^{36}Cl simulator can be found in `SimulateCl36/offline_phase.m`:

```
rho_min = 1.2;
rho_max = 1.8;
Lambda_sp_min = 180;
Lambda_sp_max = 220;
Lambda_mu_min = 1300;
Lambda_mu_max = 1700;
```

The ranges specified here must cover those of the corresponding prior distributions in the case study file (or the defaults file), namely:

```
parameters.rho_coll = @(~) UniformProposal(1.2,1.8);
parameters.Lambda_sp = @(~) UniformProposal(180,220);
parameters.Lambda_mu = @(~) UniformProposal(1300,1700);
```