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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Landslides Data Assimilation Using TRIGRS Based on Particle Filtering" *by* Changhu Xue et al.

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Thanks for your comments. The following is my reply.

General comments: In this paper, a data assimilation experiment was performed using the TRIGRS model to evaluate the stability of landslides. Because the experiment used landslide surface deformation observation data, only areas with FS <1.0 can be calculated. Although the area with FS <1.0 does not necessarily cause slope failure, the stability of the creeping landslide can be inferred based on the trend of the safety factor. If FS changes significantly and lead to deformation rate increases, then this landslide should be focused. However, there is only one equation for parameters and FS, so using FS can estimate only one parameter. Considering soil cohesion and

friction angle are indicators for determining shear strength, we selected one parameter between them. The purpose of this paper is to propose a method to investigate the trend of FS changes through data assimilation with parameter updating. In addition, considering that the observation error is relatively large, it is not accurate to use the observation data of the first day. The part of "Sensitivity analysis" is deleted, instead, the introduction of hydrological data is added.

Specific comments: 1. Thanks. The Data assimilation framework includes background and observations. Background refers to the model used to simulate dynamic processes, and observations can be direct or indirect observation data of the state. In this experiment, "background" is the uncorrected TRIGRS model and its output FS, "observations" are FS calculated from GPS/InSAR monitoring data by equation (1). Related descriptions have been added in the manuscript, pg2, line 5∼6. 2. Thanks for your suggestion. The citation and bibliography of this article has been added into the manuscript. 3. This sentence is changed to "It is located at the junction of the Eurasian plate and the Indian Ocean plate. The geological structure is complex and the geological activities are active." 4. Both GPS and InSAR observations are involved in data assimilation calculation. InSAR monitoring points are distributed throughout the landslide surface, but the distribution is uneven and does not coincide with GPS stations. So we put InSAR points and the GPS points into the grid, and some areas where the observation data is sparse are supplemented by interpolation. 5. There is an error in the expression here. In the experiment, the soil and hydrological parameters used in the model remain unchanged, the same as the TRIGRS program running without correction. These parameters were obtained by collecting local geotechnical samples. The rainfall data was obtained by bilinear interpolation from the China Ground Meteorological Information Center (http://data.cma.cn), "China Ground Precipitation $0.5^\circ \times 0.5^\circ$ Grid Data Set (V2.0)". Of course other hydraulic parameters are significant, but as the general comments replies, we can only estimate and update one parameter through one equation. During the experiment, the dynamic change of shear strength needs more attention, which determines the equilibrium state of the soil.

Therefore, we choose the shear strength indicators as parameters for real-time update. The shear strength was chosen as the parameter of interest actually. Cohesion and friction angle are the shear strength indicators. When the cohesion was chosen as the update parameter, the experiment gave similar results. Since the friction angle and the safety factor are nonlinear relationship, it is chosen to propose our method. Internal friction angle is a way to adjust the shear strength in this experiment. Some related explanations have been added to the section 3.2. 6. This part is deleted. 7. Yes. The changing friction angle is effectively correcting for inaccuracies in the hydraulic parameters. Therefore, the sensitivity analysis results are not accurate, so the relevant part is deleted. As is mentioned before, the friction angle is a way to adjust the shear strength in this experiment. It is more meaningful to analyze the correlation between groundwater and rainfall after assimilation. At last, the pressure head and rainfall are displayed in figure 17, and the correlation between them are calculated. 8. The deformation rate maps both calculated from assimilated FS and observations are displayed in figure 15.

Grammar and figures: Thanks for your suggestions. Grammar and figures have been modified.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2019-16/nhess-2019-16-AC2-supplement.zip

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