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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Data Assimilation with An Improved Particle Filter and Its Application in TRIGRS Landslide Model" *by* Changhu Xue et al.

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Thanks for your comments. The following is my reply.

Questions reply: 1. Extensive editing of English language and style required: this must be reviewed in depth. Reply: The manuscript has been revised. The text is modified in some poorly expressed places to improve the expression of English languages. 2. The improvements such as the accuracy and computation burden of the particle filter should be more clarified. Reply: At the end of section 2, the root mean square difference (RMSD) has been added as a measure factor to evaluate the accuracy. The main computation burden of the particle filter is explained in Para.2 of Sec.2: "Residual resample is a way to solve the problem of particle degeneracy which is an unavoidable

trouble in standard PF. With the recursive progress, the weights of particles are gradually concentrated on a few samples and others tend to be zero. To keep most particles effective, low-weight particles are removed and high-weight particles are duplicated. This causes that the particle sets can hardly represent the prior PDF due to the declining of particles diversity." 3. Section 4, the authors mentioned "observations are generated from the Fs by adding a disturbance with normal distribution N(0.2, 0.3)", why the mean of disturbances is 0.2 rather than 0? Reply: Due to the TRIGRS model calculate the safe factor cell by cell, without considering the interaction force between grid cells, the TRIGRS output results have systematic errors. So, we assumed a disturbance with an experience mean of 0.2. Additionally, the estimation of parameter φ has been increased in section 4. Figure 6 and Figure 7 are distribution and change line of φ respectively. 4. I noticed that the FS was chosen as the assimilated factor, why not use the displacement? Reply: In the post failure stage of landslide, the two variables, FS and displacement (in fact the integration of displacement velocity over time, dv/dt), can be converted to each other. The FS determines the integration of displacement velocity over time. When the displacement is chosen as the assimilated factor, it is necessary to convert the FS to velocity, and then accumulate to get displacement by time. This progress would magnify the error of FS, and the difference between model value of displacement and the observation would be larger. That would reduce the efficiency of particle filter. To convert the displacement to FS can control the dispersion of errors. Besides, this also reduces computational complexity. Therefore, FS is more suitable to be the assimilated factor than displacement. 5. Data assimilation is usually applied on large scale scenarios. This study employed assimilation size 10*10, I suggest you increase the assimilation size, or use true landslide monitoring data instead. Reply: In the 3rd paragraph of section 4, the size of the assimilation area has been increased. "An example of 10 * 10 grid TRIGRS model is set to be the background, and each grid cell is a square with a length of 10 meters." In this paper, a synthetic experiment is presented to verify the feasibility of the algorithm and its application to the TRIGRS landslide model. The main goal of this study is to propose a new method and prove it

can be applied to the evaluation of FS in landslide slope. Experiments of real cases is carrying out and it need some more monitoring data.

Comments reply: 1. The full name of “TRIGRS” should be given at its first appearance. Reply: Thanks. The full name of “TRIGRS” is added in the first paragraph of introduction. 2. Page 1 Line 7 and 8, I think it would be better to recognize this sentence. Reply: The manuscript has been modified to “In this work, an improved particle filter algorithm is proposed. To overcome the particle degeneration and improve particles’ efficiency, the processes of particle resample and particle transferring are updated.” 3. Page 1 Line 23, reference missing: ‘Jiang adopted the Ensemble Kalman filter to landslide movement model in relation to hydrological factors, which introduce data assimilation (DA) to landslide.’ Reply: The reference has been added. “Jiang, Y. A., M. S. Liao, Z. W. Zhou, X. G. Shi, L. Zhang and T. Balz (2016). "Landslide Deformation Analysis by Coupling Deformation Time Series from SAR Data with Hydrological Factors through Data Assimilation." Remote Sensing 8(3).” 4. Page 2 Line 14: ‘It can get good results to using...’ should be ‘to use’. Reply: Thanks. The manuscript has been modified. Some other expression errors have also been modified. The supplement is the modified manuscript.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2017-439/nhess-2017-439-AC3-supplement.pdf

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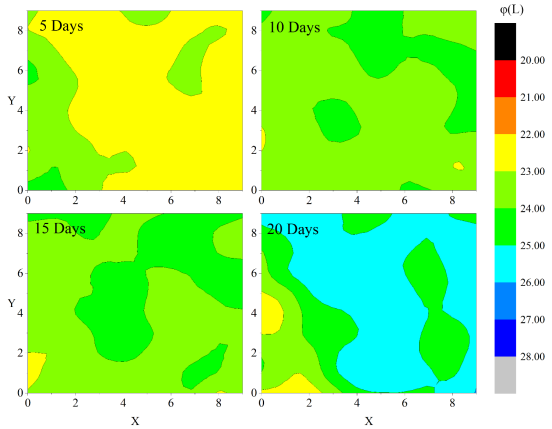

Figure 6. The distribution variation of groundwater pressure head (φ) with assimilated time. The horizontal and vertical coordinates in each graph are grid numbers of each cell.

Fig. 1.

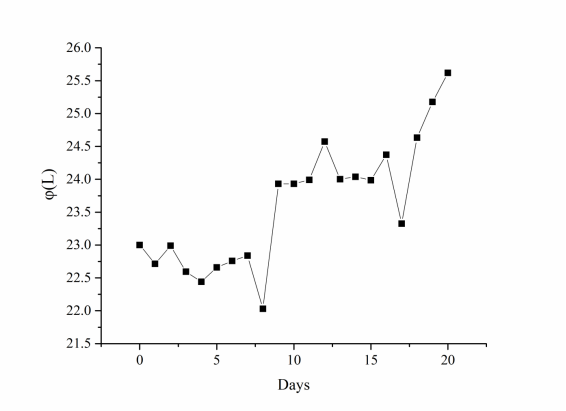

Figure 7. The changing line of the groundwater pressure head (φ) estimation of grid cell (5, 5) with assimilating time. The value is growing with the evolution of the landslide.

Fig. 2.