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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Simultaneous state-parameter estimation of rainfall-induced landslide displacement using data assimilation" *by* Jing Wang et al.

Jing Wang et al.

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Dear referee:

Thank you very much for the review and the valuable comments on our manuscript entitled "Simultaneous state-parameter estimation of rainfall-induced landslide displacement using data assimilation". We have carefully revised the manuscript and answered the questions according to the suggestions. A revised document with the correction portion red marked is attached in the supplement . Because of your suggestions, the revised article becomes better and readers can get more valuable information. We sincerely hope this manuscript will be finally accepted. Thanks again to the editors and

reviewers for their help.

Answers to comments:

1.The polynomial trend line alone (Fig. 6) seems to be a better predictor of the net displacement than the full method (SSPE accumulation prediction + polynomial trend line, Fig. 9); Please show dates rather than time steps and use the same starting and ending dates for each of the plots in Figs. 6,7,8, and 9; Inconsistencies between amplitudes of observed periodic displacements in Fig. 7 (+/-10 mm) and Fig. 8 (+/-30 mm) cast doubt on results of the SSPE assimilation prediction in Figs. 8 and 9; The additional complication of predicting the periodic displacement component seems unnecessary for the data from stations GPS03 and GPS04.

Response: Thank you very much for your advices. We are very sorry for our inexact expression. The displacement in Fig.6 is trend displacement, not the net displacement. The trend displacement is a part of net displacement and shows quasi-linear characteristics, so it fits well by polynomial. The reason why we don't use polynomial trend line to predict net displacement is that the net displacement contains periodic term. The periodic term shows violent fluctuations so that it cannot fit by polynomial; I have modified the time coordinates show in Figures 6, 7, 8 and 9 according to the requirements; Please excuse our negligence. Because the rainfall data is about triple of the periodic displacement. We scale up the periodic displacement to make sure them on a similar scale. Figure 8 shows the expanded period term displacement. Thank you for your remind and we re-run the data assimilation experiment again. Since the selection of particles in the assimilation step is random, the results in Figure 8, 9 and Table 1, 2, 3 are different from the previous ones; The goal of our research is aimed at predicting the displacement more quickly and accurately. The periodic displacement in the initial period of the landslide is really small. But as the landslide develops it will gradually increase. I also hope that I can get more data in the future to verify my method.

2.The authors have not shown conclusively that their proposed method works in a situation that is critical for hazard management; Relatively steady movement like that observed at stations GPS03 and GPS04 is relatively easy to predict and does not require a very sophisticated model to predict the displacement pattern; Displacement predictions in such a case would require shorter time steps (perhaps variable time steps that get shorter as displacement rate increases). How would that affect model performance (accuracy and computational speed?

Response: Thank you for your criticisms. We are unable to provide a conclusively warning value because the situation of each landslide is different. The induced factors are not only internal factors but also external human activities and so on. And the external human activities are difficult to predict; We have proceeded simulation experiments with particle filtering. It can also perform very well in the case of violent fluctuations. We think the advantage of our method is that it does not require a lot of geological exploration work in the early stage, which can save a lot of time to build a relatively accurate model and use a small amount of observation data to get the prediction result. It can be seen a near real-time method; We choose five days as a time step here just because of data quality control. The selection of the time step does not affect the performance of particle filter.

3.Show an outline of the landslide boundaries on Fig. 3.

Response: In Figure 3, the colored part is the entire area of the landslide.

4.Page 1, line 22. A more general reference about landslide danger to life and property is needed here.

Response: Thank you for your advice. We have added more reference in Page 1, line 23.

5.Page 2, lines 18 and 19, check citations against reference list.

Response: We have corrected the citations in Page 2, line 22 and 23.

We would like to express our sincere thanks again to the reviewers for the constructive

and positive comments. Should you have any questions, please contact us without hesitate.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2019-24/nhess-2019-24-AC2-supplement.pdf

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2019-24, 2019.

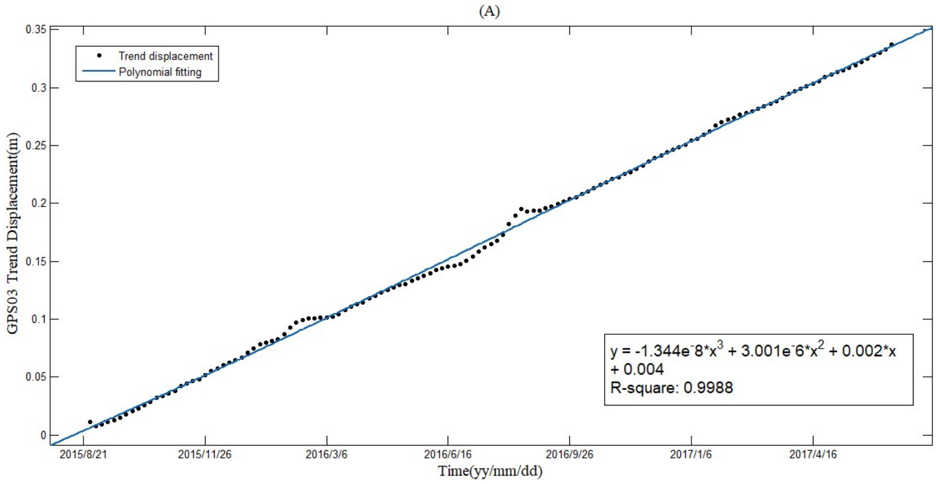

Fig. 1. Figure 6:The trend term displacement prediction of (A)station GPS03

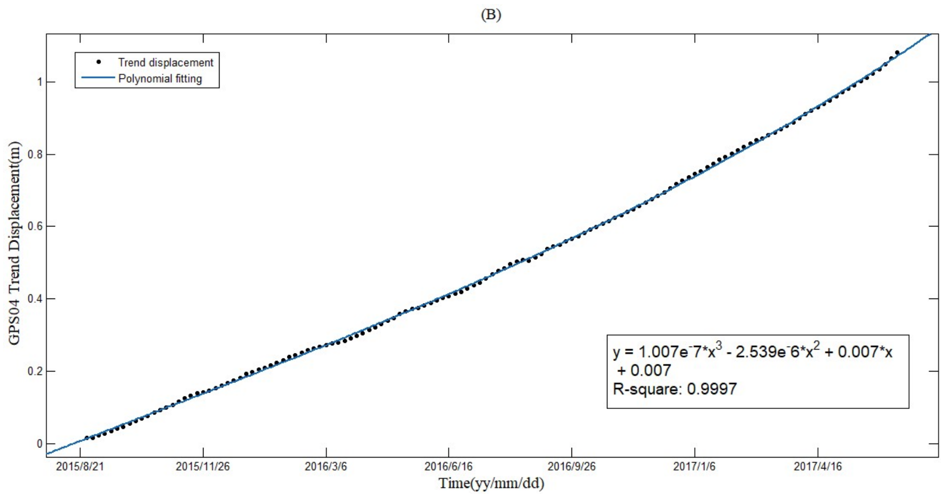

Fig. 2. Figure 6:The trend term displacement prediction of (B)station GPS04

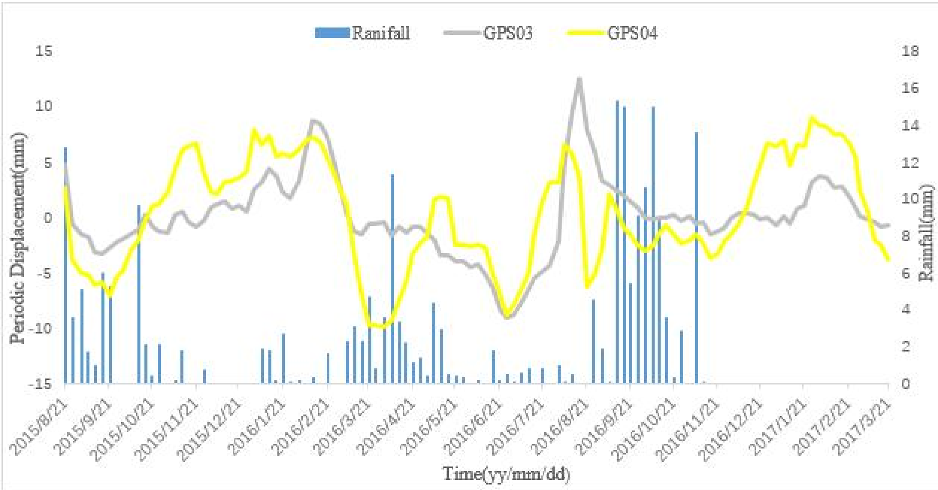

Fig. 3. Figure 7. The periodic term displacement combined with rainfall data in GPS03 and GPS04

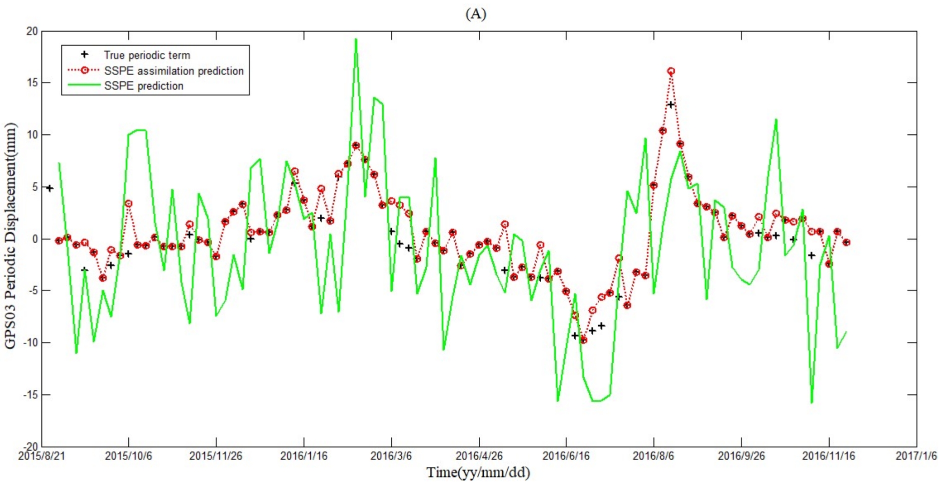

Fig. 4. Figure 8. The periodic term displacement prediction of (A)station GPS03

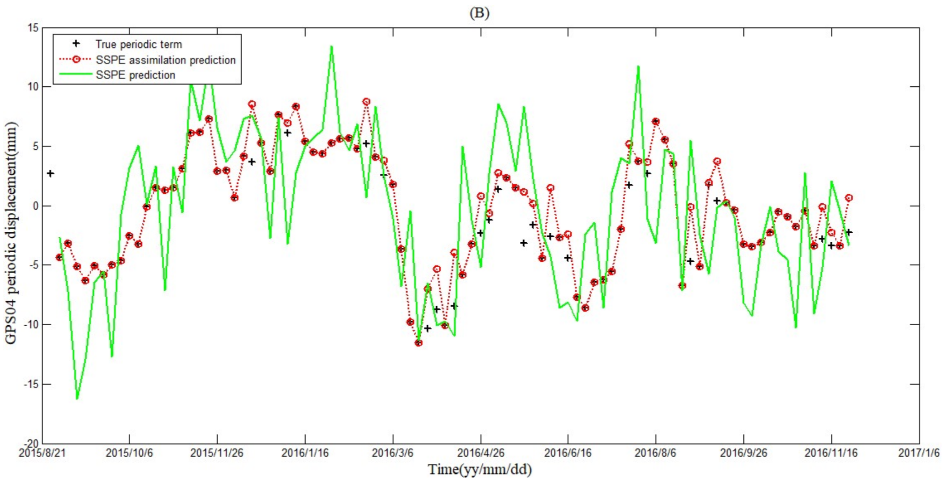

Fig. 5. Figure 8. The periodic term displacement prediction of (B)station GPS04

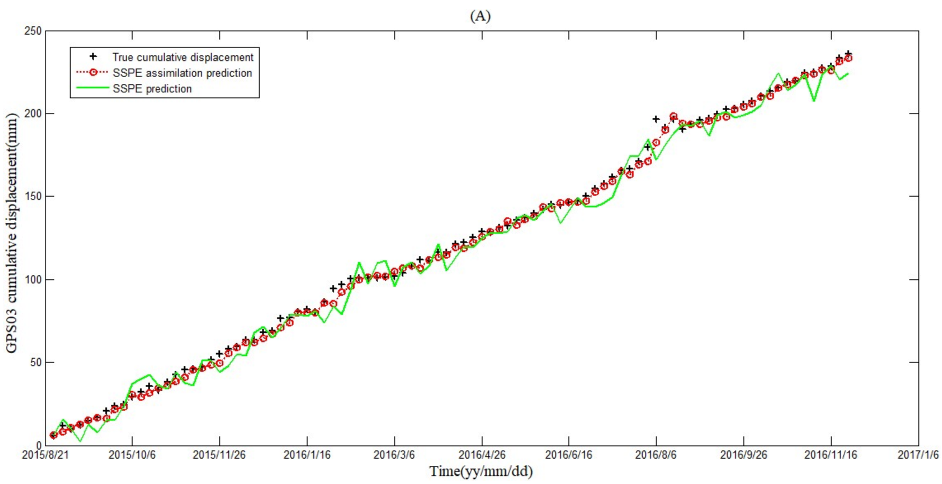

Fig. 6. Figure 9. The cumulative displacement prediction of (A)station GPS03

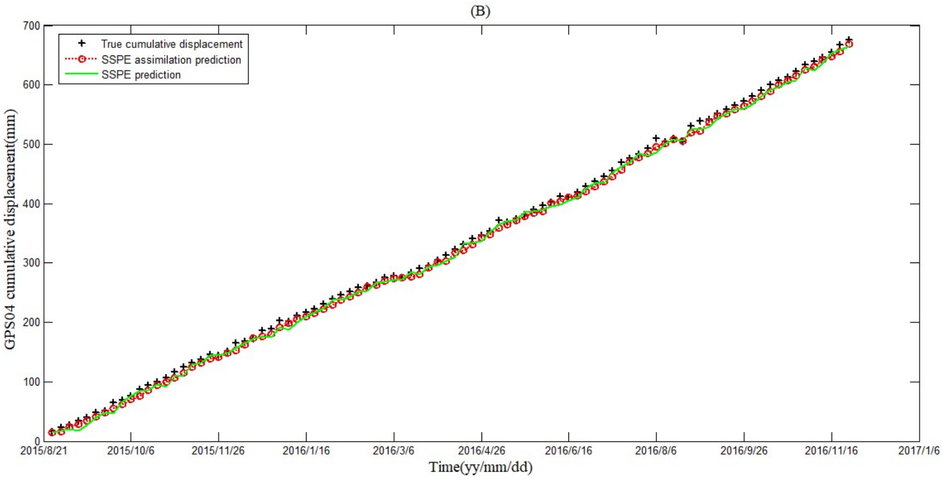

Fig. 7. Figure 9. The cumulative displacement prediction of (B)station GPS04

Table 1 Comparison between the predicted values of cumulative displacement and measured displacement using different methods in station GPS03

Time (yy/mm/dd)	Measured value (mm)	SSPE			SSPE assimilation		
		Prediction value (mm)	Difference (mm)	Error rate (%)	Prediction value (mm)	Difference (mm)	Error rate (%)
2015/10/11	32.2674	40.2287	-7.9614	-24.67	29.1589	3.1085	9.63
2015/12/16	63.3499	68.1207	-4.7708	-7.53	61.8590	1.4909	2.35
2016/4/6	116.0395	105.4518	10.5878	9.12	115.0090	1.0305	0.89
2016/6/11	144.7729	133.5143	11.2586	7.78	145.9559	-1.1830	-0.82
2016/7/6	157.6520	146.3509	11.3011	7.16	156.2981	1.3539	0.86
2016/8/11	191.482	180.9944	10.4876	5.48	190.1751	1.3069	0.68
2016/10/16	215.3067	224.5674	-9.2607	-4.30	215.4657	-0.1590	-0.07
2016/11/21	233.1672	220.3506	12.8166	5.49	231.5734	1.5938	0.68

Fig. 8. Table 1 Comparison between the predicted values of cumulative displacement and measured displacement using different methods in station GPS03

Time (yy/mm/dd)	Measured value (mm)	SSPE			SSPE assimilation		
		Prediction value (mm)	Difference (mm)	Error rate (%)	Prediction value (mm)	Difference (mm)	Error rate (%)
2015/12/26	189.1781	175.2549	13.9232	7.36	180.9129	8.2652	4.37
2016/2/21	261.1626	252.4146	8.7480	3.35	260.5177	0.6449	0.25
2016/4/1	304.7420	296.5933	8.1486	2.67	301.3644	3.3775	1.11
2016/6/6	402.9618	394.7279	8.2339	2.04	400.5510	2.4108	0.60
2016/8/1	492.6282	479.9417	12.6865	2.58	484.7087	7.9195	1.61
2016/9/26	572.1082	559.3349	12.7733	2.23	564.2868	7.8214	1.37
2016/11/11	646.0208	636.9418	9.0790	1.41	642.0225	3.9983	0.62

Fig. 9. Table 2 Comparison between the predicted values of cumulative displacement and measured displacement using different methods in station GPS04

Table 3. Comparison of MAE, MSE, RMSE performance and needed time using different methods in two stations

Method	MAE(mm)		MSE(mm)		RMSE(mm)		Execution time(s)	
	GPS03	GPS04	GPS03	GPS04	GPS03	GPS04	GPS03	GPS04
SSPE assimilation	2.2323	6.8323	9.5285	56.9071	3.0868	7.5437	0.0048	0.0059
SSPE	5.8533	7.3201	53.9320	76.1646	7.3438	8.7272	0.0844	0.0747

Fig. 10. Table 3. Comparison of MAE, MSE, RMSE performance and needed time using different methods in two stations