Nat. Hazards Earth Syst. Sci. Discuss., 3, C2975–C2980, 2016
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Natural Hazards and Earth System Sciences
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Discussions

Interactive comment on "Characteristics of landslides in unwelded pyroclastic flow deposits, southern Kyushu, Japan" *by* M. Yamao et al.

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Received and published: 15 January 2016

We greatly appreciate this useful and insightful review and have addressed all of the review comments in the following paragraphs and via substantial modifications in the paper.

General Comments: The reviewer mentioned that we should discuss the limitations of this investigation and how these results can be applied to different regions. While Shirasu deposits are limited to southern Kyushu, Japan, landslides/debris flows associated with these pyroclastic materials cause much damage and loss of life within this area. Furthermore, because of shirasu is highly susceptible to landslides, we believe that shirasu occurs in a very unique setting to investigate the magnitude and

frequencies of landslides. As such, the data sets in our paper could be useful basic information for understanding these magnitudes and frequencies and threshold behaviors for initiation of landslides. We added sentences to emphasize this in the second paragraph of the Introduction: "Although these deposits are restricted to the southern 30% of Kyushu Island, this region of Japan experiences some of the most devastating landslide and debris flow disasters in the nation (e.g., Sidle et al., 2004; Teramoto et al., 2006; Taniguchi, 2008). Furthermore, because Shirasu is highly susceptible to landsliders, this region provides a unique setting to investigate the magnitude and frequency of landslides, and the data presented herein should be useful in addressing these issues". Furthermore we now address (at the end of the Summary & Conclusions section) how our findings in Shirasu may or may not be applicable to other pyroclastic deposits; we added the following sentence: "Because Shirasu is a typical unwelded ignimbrite, it has been noted that findings related to landslide precursors (weathering) and mechanisms can reasonably extrapolated to other unwelded ignimbrites in humid regions (Chigira and Yokoyama, 2005). Nevertheless, any application of our results to other areas of unwelded pyroclastic flow deposits should carefully consider similarities and differences in weathering rates; climate; slope gradients; porosity; and other physical, hydrogeomorphic, and geotechnical properties prior to making such comparisons." Also, in response to this reviewer's request (as well as other reviewers), we have included more information on weathered Shirasu physical and mineralogical properties (see new Table 1) and as well as land cover. These additions now appear in two new paragraphs on pg. 6 of Section 2. We also introduce a newly prepared topographic (gray-shaded) map showing the locations of the investigated landslides (see new Figure 4). Since we only investigated landslides that occurred in Shirasu deposits, the 'soil' conditions are rather homogeneous throughout the study region – the main exception is weathering depth as noted by a number of investigators.

[add Table 1] Table 1. Physical and mineralogical characteristics of Shirasu based on the following sources: Yokoyama, 1970; Umehara et al., 1975; Nakano et al., 1981; Iwamatsu et al., 1989; Sugio and Okabayashi, 1994; Sako et al., 2000; Chigira and

Yokoyama, 2005; Hira et al., 2006; Takewaka, 2007. * indicates average values.

[add new Fig. 4] Figure 4. Locations of the Shirasu landslides in our database from 1985 to 2005 together with rain gauge stations in Kagoshima Prefecture. Rectangle shows the concentration of more than one-third of these damaging landslides in Kagoshima City.

Specific Comments:

Locations of the investigated landslides that occurred from 2000 to 2005 are now presented on a gray-shaded topographic map along with locations of rain gauge stations.

We regret the confusion caused by Figure 2; this is not an actual profile cross section, but rather a hypothetical illustration of the hydrogeomorphic processes that shaped the Shirasu deposits in this general landscape. Hence, this conceptual illustration was based on our assessment of various previous studies, including Yokoyama (1970). We have now reworded the introduction of this figure in the text to avoid confusion. As such, the topographic information requested by this reviewer is more appropriately included in the new map of southern Kyushu (new Figure 4). Please note this is our figure, thus now citation is needed in the caption of Figure 2.

We understand this reviewer's request to include two additional graphs in Figure 6; however, although we initially considered including this comparison, we decided against it because the slab-type failures typically only occur on very steep slopes, whereas the slightly deeper landslides occur on less steep slopes. The fact that these very shallow failures only occur on very steep slopes is now better emphasized in the paper - see the following new sentences and modifications: 4th paragraph of Introduction (bottom of pg. 3) and the first paragraph of Section 3.4. It is our feeling that including these additional graphs may cause some confusion due to unrealistic scenarios. The safety factor in each case was calculated for an assumed homogeneous, infinite slope – this is now described as follows (with the requested reference): "Slope stability for the two described scenarios was assessed using a model that assumes a

homogenous, infinite slope (e.g., Sidle and Swanston, 1982):".

Technical Comments:

We have adopted the recommended terminology of API, and have better described this at first usage in Section 2.

A reference is now included for the FS equation (see previous response).

Accumulated rainfall is the amount of rain water that is retained (by tension) in the regolith, whereas API (we now try not to use antecedent rainfall in response to this reviewer's suggestion) is a calculated index. We clarify this distinction in the text in the first paragraph of section 3.4.

Some explanation of unit weight values is now provided in the text (referenced to the new Table 1); this now appears as: "In calculations, unit soil weight was allowed to vary from totally dry (9.32 kN m-3) up to near-saturated conditions (14.81 kN m-3), based on reported values for Shirasu (Table 1) and calculated weight increases with increasing moisture content. Internal angle of friction was assumed to be 32 degrees, consistent with published values (Table 1)."

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/3/C2975/2016/nhessd-3-C2975-2016-supplement.pdf

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Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 3, 6351, 2015.

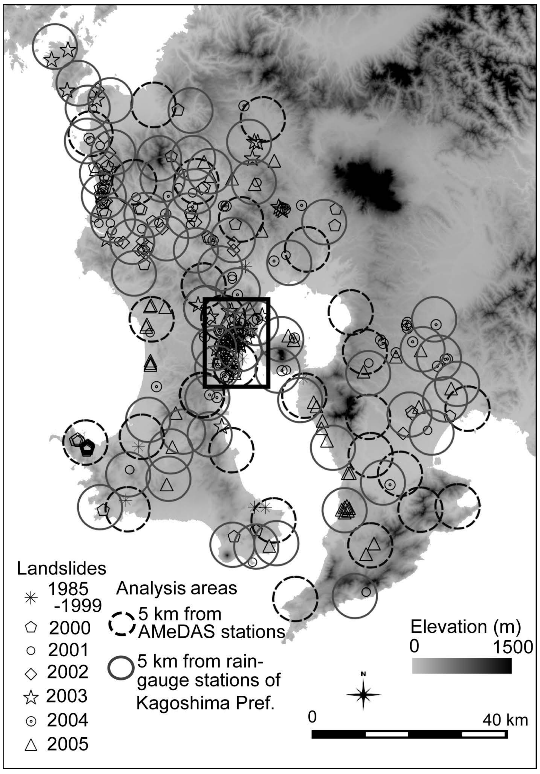

Fig. 1. new Fig. 4

Percent sand	77%*
Percent silt	20%*
Percent clay	3%*
Porosity (%)	44-65%
Particle density (Mg m^{-3})	2.3-2.55
Bulk density (Mg m^{-3})	0.9-1.2
Cohesion (kPa)	0-10
Internal angle of friction (°)	30-40°
Saturated hydraulic conductivity (m s^{-1})	10^{-5}-10^{-6}
SiO_2 content	70%*
Al_2O_3 content	14%*
Alkali oxide content	8%*

Table 1. Physical and mineralogical characteristics of Shirasu based on the following sources: Yokoyama, 1970; Umehara et al., 1975; Nakano et al., 1981; Iwamatsu et al., 1989; Sugio and Okabayashi, 1994; Sako et al., 2000; Chigira and Yokoyama, 2005; Hira et al., 2006. * indicates average values.

Fig. 2. new Table 1