Response to RC C2387 (Referee #3):

We express our gratitude for these helpful review comments which we have addressed in the paragraphs that follow.

General comments:

The reviewer noted that the section on stability analysis (Section 3.3) abruptly appeared and was not strongly associated with the analysis of the landslide data set. We composed a new introductory paragraph for Section 3.3 (now Section 3.4 due to our reorganization of the paper) to describe why we conducted this stability analysis. Following this introduction, the slope stability analysis is described. This introduction should provide the necessary transition. The new introductory paragraph we drafted is:

To better understand how shallow, slab-type failures and slightly deeper landslides in Shirasu are affected by increased weight and loss of suction during periods of progressive wetting, we assessed scenarios of how changes in these conditions may influence slope stability. Two cases were examined, one with shallow soils (0.5 m) and very steep slope gradient (72°) typical of slab-type failures, and another with slightly deeper soils (1 m) and a slope gradient of 40° (typical gradient for this type of failure). Firstly, we examined only the effects of increased soil weight due to rainwater accumulation on the stability of these pyroclastic flow deposits and then assessed the effects of both increased soil weight and the concurrent loss of cohesion (suction decrease). These two factors may contribute to slope failure even in the absence of a positive pore pressure developing within the soil mantle.

The reviewer suggests that the two proposed triggering mechanisms for landslides in these pyroclastic flow deposits (positive pore pressure accretion and the combination of increased mass and loss of suction due to progressive infiltration of rainwater) be mentioned only in the Discussion section after the results have been presented to avoid confusion. This comment conflicts a bit with the suggestion raised by RC C2296. We have modified the text in the Results section as follows: We retain the short mention of the trigger mechanisms in the Introduction, as these are based on others findings. We introduce the concept of how different types of Shirasu landslides are likely initiated via different mechanism in Section 2 (third paragraph). We removed any mention of trigger mechanisms from the first three subsections of the Results section. We moved former Section 3.3 to 3.4 where we now illustrate how increased weight and loss of suction may affect Shirasu landslides. And then we address these mechanisms (by inference) in both the Discussion and Summary and Conclusions sections. We feel that this reorganization and the related changes should satisfy both this reviewer's concerns and those of reviewer RC C22396.

Specific comments:

1. As noted near the bottom of pg. 3 of the paper, deeper landslides rarely occur in Shirasu deposits, and if they do, they occur in deeply weathered deposits on gentler slopes. The occurrence of these is more related to the weathering depth. More typically, Shirasu weathers rapidly and landslides occur within the relatively shallow weathered zone during a storm event (the two types of landslides noted and their respective depths, depend on slope gradient). Because we do not have accurate volumes and failure depths for most of the landslides in our analysis, we cannot unequivocally say that none of the landslides during major storms were deep-seated. However, the incomplete dimensional data we have suggests that all or at least most of these landslides fit

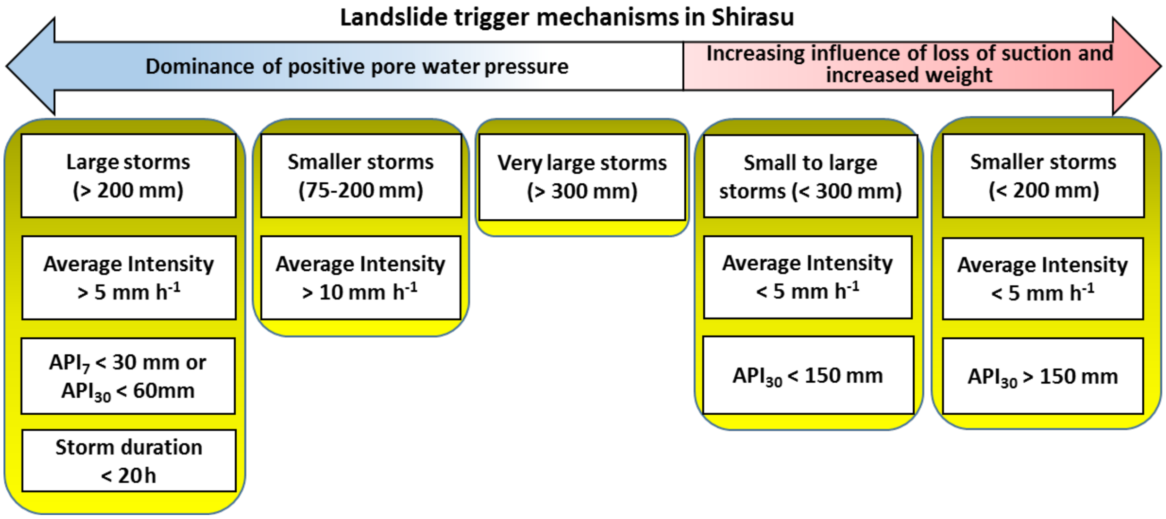
into the two categories we note – i.e., slab failures (< 1 m deep) and slightly deeper landslides on gentler slopes (1-2 m deep). We believe that our original categorization of landslides as "shallow slab-type failures" and "deep planar landslides" as led to confusion and we have modified this as noted in our response to RC C2296 – we now call the latter "slightly deeper planar landslides". We have also tried to clarify this issue (emphasizing that most all Shirasu landslides are relatively shallow) by adding the following statements in the fourth paragraph of our Introduction: "*During typhoon Nambi (September 4-6, 2005), more than two-thirds of the landslides around Tarumizu City (southeastern Kagoshima Prefecture) occurred in Shirasu deposits, and most of these were shallow failures (Teramoto et al, 2006). The dominance of these shallow, planar landslides in Shirasu is attributed to the rapid weathering of this unwelded material on steep slopes, thereby promoting repeated removal of the surface weathered layer (Shimokawa et al., 1989; Yokota and Iwamatsu, 1999; Chigira and Yokoyama, 2005). The shallowest of these planar failures occur on the steepest slopes (Haruyama, 1974; Sako et al., 2000; Teramoto et al., 2006).*

2. Evapotranspiration rate was calculated for all 7 or 30 days prior to landslide events; see changes made in the last paragraph of Section 2.
3. The reviewer notes that it was difficult to follow the description of the criteria we suggested for different landslide types because mechanisms of landslide initiation are involved. We have taken the advice of this reviewer and put together a chart that addresses the empirical criteria (based on our analyses and understanding) that affect the different landslide trigger mechanisms in Shirasu (new Figure 11). While this diagram is quite general, hopefully it is helpful. We retained subsection 4.1 as we added another subsection to the Discussion (for empirical criteria). We now provide a better transition sentence to introduce the rainfall intensity – duration landslide thresholds and related API assessments (section 4.1): "*To illustrate the importance of API on certain types of landslides in unwelded pyroclastic flow deposits, we employ typical rainfall intensity – duration threshold analysis*." We have also modified several sentences later in this section to hopefully avoid any further confusion. The last paragraph of Section 4.1 now reads:

While many landslide producing storms plot near the Sidle and Ochiai (2006) threshold, 21 landslides were triggered by events plotting below the threshold (Figure 9). Only two of these 21 events had API_{30} *values < 235 mm and more than half had* API_{30} *values > 300 mm. Given this high level of water stored in the porous Shirasu deposits prior to the triggering storms, most of these 21 landslides and some of the events positioned just above the threshold are likely influenced by the combined effects of the accumulated mass of rainfall and the associated loss of matric suction within these deposits.*

[Add new Figure 11 here]

Figure 11. Diagram of empirical criteria that affect different landslide triggering mechanisms in Shirasu deposits in southern Kyushu.



The first paragraph of subsection 4.2 now reads:

Based on our analyses and understanding of threshold behaviour for different types of landslides, the following empirical criteria are proposed to identify landslides triggered primarily by pore water pressure during individual large storms: $API_{30} \leq 60$ *mm, average storm intensity > 5 mm* h^{-1}*, and duration < 20 h (Figure 11).* API_{30} *values ≤ 60 mm suggest that increases in mass and decreases in suction due to long-term accumulated soil water would not be significant landslide trigger mechanisms. Additionally, an average storm intensity of 5 mm* h^{-1} *provides a good segregation criterion for landslide populations based on total precipitation – duration plots (Figure 7). Of the 93 landslide events during large storms, 40 occurred when* $API_{30} \leq 60$ *mm and average storm intensity > 5 mm* h^{-1}*, thus strongly suggesting rapid pore water pressure response as the cause. Additionally, the six large, lower intensity storms highlighted in Figure 8b (total precipitation > 300 mm and average intensities ≤ 5 mm* h^{-1}*) likely triggered landslides due to pore pressure response. For the smaller storm category (≤ 200 mm), we can assume that higher average intensities (> 10 mm* h^{-1}*), together with > 75 mm and ≤ 200 mm of rainfall up until slope failure, will trigger landslides by positive pore pressure response during storms (Figure 11). These criteria account for 14 landslide events from the small storm category that could be triggered by positive pore pressure. In cases where API values are high, it is difficult to use API to separate landslide-producing storms in which the trigger mechanism was the combined increase in soil mass and loss of suction from those triggered by positive pore water pressure because many of these events were large enough to initiate landslides via positive pore pressure accretion alone. During smaller storms, and especially less intense storms, landslides are likely caused by a combined increase in soil mass and loss of suction when* API_{30} *is high. These criteria for Shirasu landslides are outlined in Figure 11. Our analyses could not account for soil piping effects as this was not noted in the landslide records.*

Technical Corrections:

- Subheading 4.1 is retained and a new subheading 4.2 is introduced.