## Answers to Comments from Anonymous Reviewer #2:

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R2_Comment #1a:

"…The novelty of the approach and findings is not significant for several reasons: - linear correlation is applied which is extremely questionable for geological processes highly influenced by non-linear relationships and transients?..."

R2_Answer #1a:

The R1_Answer#5 given to Reviewer 1 can also apply to this comment. In summary, we have performed time-lagged scattered plots tests to investigate the linear relationship between variables and, actually, we found out that a linear dependency can be assumed to exist ($R^2$ values between 0.6 and 0.78) for the following time series combinations: Piez. Depth vs. Piez. Depth.; Displ. RATE Vs- Displ. RATE; Piez.depth vs. Displacement RATE. Thus, we believe that the cross correlation analysis of such variables is fully justified and, at the same time (as specified in R1_Answer #5) we propose to eliminate the cross-correlations that have proven non-linear, which are only these including rainfall.

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R2_Comment #1b:

"…- the authors filtered the data applying signal-to-noise methods to remove instrumental errors – what is the effect of this SNR ? how many data were removed and what is the influence on the correlations?..."

R2_Answer #1b:

As presented in the paper, we have applied a Fourier Filtering that operates in the frequency domain. This have been done after a careful observation of the raw time-series evidencing "noise" that appeared after the data-logger were replaced (such replacement was made prior to the time period analyzed in this paper). As a consequence, after having identified the exact temporal frequency of this electric noise (which corresponds to a return period of 30h), we have selectively removed it. Therefore, filtering has not influenced the cross correlation of our time-series, as it is clearly visible in figure 5, were both the raw and the filtered time-series are presented.

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R2_Comment #1c:

"… seasonal patterns are observed in the time series, and seasonal de-trending should be applied before applying CCF – it is not very clear how the authors pre-processed their data…"

R2_Answer #1c:

To apply the cross-correlation function the displacement time-series have been converted into differential displacements, i.e. the displacement occurred within the 20 minutes sampling interval, which is essentially a displacement rate (velocity). This allowed avoiding any complicated de-trending processing. In order to avoid misunderstandings, we'll therefore change any reference to displacements into "displacement rate". For the same reason, displacement rate will be plotted in figure 2a instead of cumulative displacements.

R2_Comment #1d:

"…- the observation time series are also questionable…"

R2_Answer #1d:

The observation time-series represent a rare case of long (three years) monitoring series recorded at a landslide site. Previous papers on the Vallcebre landslide presenting the monitoring devices used represent a benchmark for the Engineering Geology scientific community. Furthermore, the high frequency sampling of 20 minutes gives space to very accurate considerations of the occurring geological processes. So we fail to see the justification of this comment.

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R2_Comment #2:

"…For instance, it has been demonstrated by several authors that effective rainfall is better correlated to piezometric variations, than net cumulative rainfall. What is the argument of using net rainfall for the analysis?..."

R2_Answer #2:

Since the analysis proposed is not focused in the definition of the daily relationship within the variables analyzed but in evidencing the global dependencies resulting in a long term perspective, we decided to use the net rainfall. As a matter of fact, the use of net rainfall would result equilibrated at the end of each hydrologic year. In any case, because of previous comments pointing to non-linear relation, that has been verified, we propose to eliminate the rainfall parameter from the cross-correlation analysis so that R2_Comment #3 is implicitly satisfied.

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R2_Comment #3:

"…Further, snow might impact the water budget. Did the authors consider the possible additional input of waters on the slope?..."

R2_Answer #3:

Since we plan to revise the paper eliminating cross-correlation regarding precipitation, (rains and snowfalls) the R2_Comment #3 will be implicitly satisfied. Nevertheless, it is worthwhile recalling that, unfortunately, we have no reliable statistics on the snow fall in Vallcebre since there are no direct measures of it. In the past, Viladrich L (1989 - Neva o no neva? . Erol, 26: 41-45 (in catalan)) recorded an average of 9 snow events per year for the period 1958-1988, mostly concentrated between December and April. In his report, a snow event may consist of few snowflakes melting after the contact with the ground and snow fall followed by rain. For our experience, snow stands occasionally on the ground at Vallcebre. Most of the fallen snow melts during the next few days. However, during some big events, such as in December 1996, January 1997, or in March 2010 (outside the analyzed period), the snow may have lasted on the ground for more than one week. As mentioned in the manuscript (p.4 lines 5-6), all the wire extensometers display a seasonal trend, with accelerations in spring and fall (periods with higher

rainfall rate) and a number of short term acceleration periods after specific precipitation events. As there is no permanent snow cover in winter, we believe that it is reasonable to assume that the acceleration is mostly controlled by the rainfall pattern and, to a lesser extent, by the toe erosion (this is an assumption that has been confirmed by the results of the present manuscript).

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R2_Comment #4:

"…Further, the piezometric depths should be transformed in hydraulic heads or better in pore pressures above the slip surface for a consistent analysis…"

R2_Answer #4:

We do not believe that this is necessary since we are not performing limit equilibrium analysis or physical modelling. The time series of pore pressure would have the same pattern in time of the piezometric depth time-series. It is noteworthy to recall that in cross-correlation analysis what matters is the pattern of the time series, i.e. variation in time, of the processed time-series. Therefore, transforming piezometric depth into hydraulic heads or *pore pressures above the slip surface* would not give any additional information to the analysis.

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R2_Comment #5:

"…Further, the authors should discuss the characteristics of the studied period regarding the long-term evolution of the slope. Is the period 1999-2001 representative of a low/high geomorphological activity of the slope, or a period of interest because many data/sensors were available? Some justification is needed especially because the approach could be tested on the complete monitoring dataset available for the landslide (at least for some combinations of parameters such as rain and displacement). This would possibly give more significance to the work and reveal some changes in the behavior in time…"

R2_Answer #5:

We provide here the same answer given to reviewer 1 (see "R1_Answer #6").

Yes, other data exist. However, we can argue that: (i) the analyzed time interval (from 01-Jan-1999 to 01-jan-2002) covers 3 years characterized by variations of velocity and it is in any case representative of the "ordinary" mobilization pattern of the landslide (ii) the analyzed time interval it is the longest available interval characterized by full continuity of data. So yes, we might have analyzed also other periods, but on separate calculations, since continuity of the time-series is a discriminant for the application of the cross-correlation function. To exemplify our arguments, we might include in the revised paper (if the editor believes it might be necessary) the figure 1, which shows the average displacement trend of the landslide (≅25cm/year) over the 15 years-period of measurements , evidencing how the analyzed period is in line with all other "ordinary" years (that are different from the "unusual" period 1997-1998, which was characterized by velocities higher than the usual (≅50 cm/year)), and how, after 2002, some gaps start to appear in the time series.

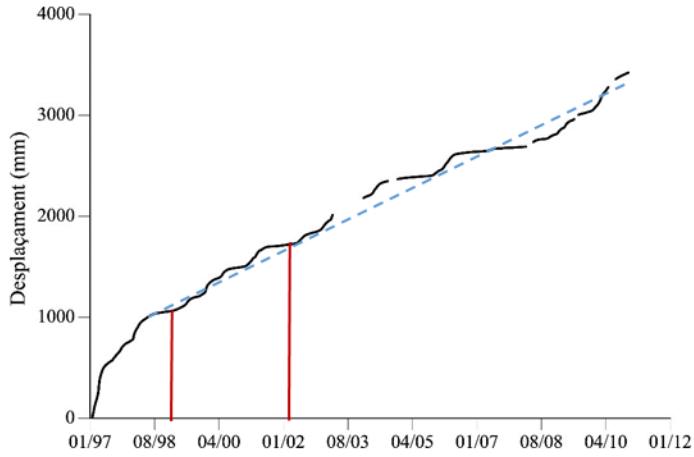


*Figure 1: Cumulative displacements of the wire extensometer S-2 during the period 1996-2012.*

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R2_Comment #6:

"…The discussion section is weak. I would like to have a discussion on the significance of the time lag statistically calculated by the authors with regard to the many hydrological models that were applied on this slope…"

R2_Answer #6:

Actually, no complete hydrological analysis/modelling has been carried out so far. We run a hydrological model (Transin) to calibrate the hydraulic parameters modelled (permeability and heads) against the values obtained with the pumping tests and the observed groundwater table (Corominas et al 2008). In the analysis performed in Corominas et al. (2005) we computed the landslide displacements and velocities from groundwater level changes considering a viscous term. In the latter work we mentioned (p. 90) that peak water levels were attained at different times, depending on the permeability of the adjacent material. Boreholes (S4) located on the graben had a faster response and drainage than the rest. We also observed (p. 91) some synchronism between the groundwater level changes and the displacements at S2 and a lack of correlation of the event in January 1997, which could be caused by toe erosion by the Vallcebre torrent. This was only an hypothesis that this work with CCF supports.

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