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Comment

Interactive comment on “Atmospheric circulation patterns, cloud-to-ground lightning, and locally intense convective rainfall associated with debris flow initiation in the Dolomite Alps of northeastern Italy” by S. J. Underwood et al.

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Received and published: 22 October 2015

This paper presents new work on understanding atmospheric conditions prior to debris flows in the Dolomites, Italy. It is important to learn more about the atmospheric conditions under which these debris flows occur and it is valuable that the authors consider the progression in time of the different atmospheric features, rather than just a static image. However, at this stage I feel revision is needed. The method in parts is vague. The choice for particular atmospheric variables was unclear, as was how the

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atmospheric circulation patterns were generated. And while I think there are some interesting results, sections 6.1-6.12 were difficult to follow and therefore hard to assess if the conclusions matched the results. In my opinion, while the paper fits within the scope of NHESS, further clarification of the methodology and restructuring of some of the results and discussion is required. My specific comments are below, followed by a few minor technical comments.

1 Specific comments

A better description of all the atmospheric variables used is needed. For example, in Section 5, did the authors use the NCEP divergence field, or did they based the divergence and PVA purely on the 500hPa charts? I also wonder why other variables such as CAPE were not used. LI is a simple measure to indicate instability (good), but its looking at only one level.

Locally intense convective rainfall - the term is use throughout the text, but not clearly defined. For each event, was the rainfall distribution examined, with the most intense rainfall in the area of debris flow initiation? Unless there was a specific definition, I would refrain from using the term LICR outside of the introduction/study area and discussion/conclusion part, and just use rainfall. It also makes it easier to read than using LICR.

The purpose of the meso-alpha scale is unclear to me. I think the authors use two scales to show that both have a relationship with debris flows, but this was not clear. Could the alpha scale be removed to simplify the discussion? Otherwise, the reasoning behind two meso scales should be clearing indicated in the methodology section.

In many places I miss the link with debris flows (other than defining when the critical interval is). Could anything be said on the magnitude of the debris flow events? I appreciate that an in depth analysis is out of the scope of this work, but any information

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about differences in the events would be beneficial (this could also just be as part of the discussion at the end).

Just a note on the writing: in places the text can be very verbose with superfluous add-ons (e.g. *one may view page 5722, reader should be mindful*). Removing these would both make the text shorter and easier to follow.

The title is very long and should be simplified: (e.g. Atmospheric conditions associated with debris flow initiation in ...).

1.1 Introduction

Page 5718 Line 25-26 Irrelevant references

Page 5719 Line Different reference needed. Current reference refers to Venice and surrounding coastal area, not the Alps.

Page 5719 Line 9-10 Reference needed

1.2 Background

While the authors convincingly argue that we need to understand better debris flow hazards, there needs to be a better reasoning on why they are considering particular atmospheric variables and which ones (e.g. there is no mention on the use of lightning data in the background or introduction). The consideration of different spatial scales should also be addressed here (why and which studies deal with the synoptic scale, and which ones and why deal with the local scale).

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1.3 Study area

Page 5722 Line 1 - What is critical rainfall? Should be defined here or removed.

1.4 Data and methods

The atmospheric variables that are considered should be introduced and briefly described in the methodology section. In the next section, for group 1, vorticity is discussed, in group 2 it is the divergence. The amount of PVA is given, but then do not elaborate the upper level divergence (what level, what amount?). It would also be reasonable to explain the lifted index here (can help the reader understand what the values mean. E.g. unstable, slightly unstable).

The method for the classifications of flow regimes is not clear. Particularly as later on in the article you base your calculations on the individual flow regimes either more information should be provided about the manual rules based method/a reference given to another article where it is explained/or some evaluation score for the classifications should be given. Right now, particularly as I cannot read the labels for the 500hPa heights, I am unable to determine if the classification was good or not.

Page 5722 Line 25-27 you should reference your own table 1 rather than the table in another publication (particularly as you indicate in the table where the events come from). I also found it confusing as a reader that here you mention 10 debris flow events (5722 line 25) and then 5723 9 mention 12 debris flow events. This information is in the table anyway.

Page 5723 solar h convention - I am not sure what this is. I think it is sufficient to state: All event times were converted to UTC to conform to the conventions of the other data sets.

Page 5724 Lines 6-7 this is in reference to debris flow events, not lightning, so should

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be with the earlier paragraph on debris flows I think?

Page 5724 end - start 5725 All of the references refer to US based studies. As the study area is in Europe, I suggest limit the number of US case studies and provide reference to European ones as well. e.g. Raible, C. C. On the relation between extremes of midlatitude cyclones and the atmospheric circulation using ERA40. Geophysical Research Letters 34.7 (2007).

1.5 Analysis

See the first two comments under : Data and Methods. Without understanding the methodology for the classification, it was difficult to comment on this part. Provided the classes are sufficiently different, the most of explanations appear sound.

Page 5727 line 22 the term omega is not explained

Page 5729 Line 12 from Figure 6, even at T-48 there appears to be a cut off low

Page 5729 Line 19 not sure what a *slacked configuration* is.

Page 5729-end to 5730 line 1 should be rephrased.

1.6 Multi-scale

I found this section difficult to follow as a whole. I would have preferred the authors group the events based on a particular feature (such as debris flows with no lightning in the meso-beta scale, those with only a moderate amount and those with higher amounts of lightning) comparing and contrasting the other variables within the group, rainfall, LI etc. Was there anything in common for the debris flow events with no lightning in the SH group? How about ones that had peak flash values < 50? Particularly as there is no control group (events without debris flows), it is difficult to determine what

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is significant in the results presented. I suggest a restructuring of this section.

Page 5731 Line 5-7 For which scale are the variables extracted? (meso-alpha, beta)? Or did you just take 1 grid box? The 2.5x2.5 degree is quite large.

Page 5732 Line 27 LI of -3.0 is generally considered unstable, not very unstable. Or are you basing the phrase textitvery unstable on something else?

Page 5745 Lines 3-5 Did you evaluate the RH and temperature from the reanalysis data to confirm this?

Page 5745 Line 70.62 would not be a strong correlation for only 12 values, particularly as it is not signification at the 0.01 level (for 12 samples $r > 0.708$).

1.7 Conclusion

This section should be titled (general) discussion and conclusion (or split into two), as new information and points of discussion are brought up in this section. Some things I am missing from the discussion (for this section or possibly earlier):

- Discussion on the limitations of the datasets used.
- There needs to be a discussion on the magnitude of the peak cloud-ground flashes. Based on the events, there is a wide range of flash peaks :15 to 140 flashes in 5 minutes (therefore, would not be able to determine when the flash peak was until after the event). This is somewhat eluded to at the end of section 6.14, but it is vague.
- Comparison with other areas: As the authors point out, there has been little re-search on atmospheric conditions with debris flow initiation specifically. However, there is much more on intense/heavy precipitation. How do the LI, omega etc.

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values differ from other studies? Are they lower because the NCEP data was used instead of soundings?

2 Tables and Figures

The size of the figures is generally good, although some parts of the figures are unclear, and more explanation in the captions is needed.

Figure 2 and 3 include in both captions the distinction between the box and circle domains (e.g. The synoptic scale domain including the area of the meso-alpha-scale (rectangle), meso-beta-scale (circle) domains)

Figure 3 cannot read what numbers are shown in the boxes in Figure 3. Also no reference to what they are in the caption.

Table 1 missing the reference for Degetto et al in the reference list

Figure 4-6 Cannot read the numbers on the 500hPa charts. Perhaps bigger numbers and fewer lines? You also need to explain what the dashed and solid lines are (troughs and ridges I think), and what the grey shading is in relation to? It may also help the reader to include the lat and longitudes (as you refer to them in the text).

Figure 7-18 I prefer the figures in the supplementary material B- especially they show the 6 hours before and after the debris flow. Would it be possible to use these figures instead, adding the rainfall (like the current 7-18) and draw a box or line around the critical period?

3 Technical comments

Page 5720 line 9 missing a space (isalso)

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Page 5720 Lines 18 and 19 flash not flashy

Page 5721 Line 16-17 Awkward sentence, rewrite

Page 5723 Line 6 reference missing from the reference list

Page 5732 line 20 remove the word textitto

Page 5741 Line 14 n missing (should be *pattern*)

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 3, 5717, 2015.

NHESD

3, C2097–C2104, 2015

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