The paper is suitable for NHESS. Unfortunately is not acceptable in present form. There are the following main deficiencies:

- In the abstract authors should resume what they did instead of writing a sequence of sentences in which the reader gets lost. If the writer is right, they should write that starting from a forecasting (WRF) corrected using data of 12 meteorological stations 4 distributions combining…………were used.

A: Our apologies. Now, we modified the abstract putting in relevance the main findings of our contribution.

Original Abstract:

Abstract. Rainfall-Induced Landslide Early Warning Systems (RILEWS) are critical tools for reducing and mitigating economic and social damages related to landslides. Despite this critical need, the Southern Andes does not yet possess an operational-scale system to support decision-makers. We propose RILEWS using a logistic regression system in the Southern Andes. The models were forced by corrected simulations of precipitation and geomorphological features. We evaluated the precipitation using the Weather and Research Forecast (WRF) model on an hourly scale. The precipitation was corrected using bias correction approaches with daily data from 12 meteorological stations. Four logistic and probabilistic models were then calibrated using Logit and Probit distributions. The predictor variables used were combinations of the slope, corrected daily precipitation and data preceding the events (7 and 30 days previous) for 57 Rainfall-Induced Landslides (RIL); validation was by ROC analysis. Our results showed that WRF does not represent the spatial variability of the precipitation. This situation was resolved by bias correcting. Specifically, the PP_M4a method with Bernoulli distribution for the occurrence and Gamma for the intensity produced lower MAE and RMSE values and higher correlation values. Finally, our RILEWS had a high predicting capacity with an AUC of 0.80 using daily precipitation data and slope. We conclude that our methodology is suitable at an operational level in the Southern Andes. Our contribution could become a useful tool in the mitigation of impacts related to climate change.

Modified abstract

Abstract. Rainfall-Induced Landslide Early Warning Systems (RILEWS) are critical tools for reducing and mitigating economic and social damages related to landslides. Despite this utility, the Southern Andes do not have an operational-scale RILEWS yet. In this contribution, we present a pre-operational RILEWS using the Weather and Research Forecast (WRF) model and geomorphological features coupled to logistic models in the Southern Andes. The models have been forced using simulations of precipitation. We correct the precipitation derived from WRF using 12 weather stations through a bias correction approach. The models were trained using 57 well-characterized Rainfall-Induced Landslides (RIL) and validated by ROC analysis. We show that WRF does not represent the spatial variability of the precipitation. Therefore, accurate precipitation needs a bias correction in the study zone. Accurate precipitation simulations allow RILEWS with high predicting capacity (area under the curve, AUC of 0.80) using daily precipitation data and slope. We conclude that our proposal is suitable at an operational level. The

> proposed RILEWS will become a support in the mitigation of RIL events related to climate change.

- The abstract and the introduction seems two separate topics. In the abstract a forecasting model and 4 four logistic models were used combining precipitation and slope, while in the introduction a mesoscale logistic model is used. At lines 86-92 it is written that a mesoscale model provides precipitation data that are corrected with the data of the stations and combined in a logistic model with geomorphological features.

A: Our apologies. Now, correct line 53 from “the implementation of a mesoscale logistic model” to “the implementation of a logistic model”. Moreover, we rewrite the introduction to be a more comprehensive introduction.

Original introduction manuscript:

> Rainfall-Induced Landslides (RIL) are one of the most frequent and dangerous natural hazards. They can affect critical infrastructure and highways in populated areas (Chikalamo et al., 2020; Fustos et al., 2020a; Peruccacci et al., 2017). In recent decades, the occurrence of RIL events has increased with devastating effects, including loss of human life and destruction of the natural and urban environment (Marjanović et al., 2018). In South America, RIL has caused high social and economic impacts; they require better evaluation in future (Sepulveda & Petley, 2015). Nowadays, Rainfall Induced Landslide Early Warning Systems (RILEWS) become a powerful alternative for mitigating human losses and reduced infrastructure damages (Guzzetti et al., 2020; Chikalamo et al., 2020; Hermle et al., 2021). The present work evaluates the design of a RILEWS using a mesoscale atmospheric model coupled to a logistic discriminator in the Southern Andes.
>
> Due new rainfall scenarios related to climate change, RILEWS have become increasingly used in recent years, reducing the vulnerability of populations using different approaches (Peres & Cancelliere, 2014; Segoni et al., 2018; Fan et al., 2019; Tiranti et al., 2019; Thirugnanam et al., 2020; Lee et al., 2021). RILEWS based on intensity/duration curves that do not consider the effect of soil moisture, leading to bias in their predictive capacity (Marra et al., 2017; Zhao et al., 2019; Chikalamo et al., 2020). Some RILEWS use historical precipitation data with long-term observations, climate reanalysis models and atmospheric mesoscale models (Lazzari & Piccarreta, 2018; Tichavský et al., 2019). Moreover, atmospheric mesoscale models have shown a high uncertainty in areas with scarce meteorological stations and complex topography. Recently, the integration of mesoscale atmospheric models with local weather stations allowed areas susceptible to RIL to be defined by determinist numerical models (Fustos et al., 2020a). Therefore, a correct implementation of mesoscale models could allow the implementation of this source of information in RILEWS.
>
> In recent years, mesoscale models showed incapable of representing precipitation fields suitable for RILEWS in areas with complex topography like the Southern Andes (Yáñez-Morroni et al., 2018). Currently, mesoscale models are restricted to the quality of their atmospheric forcings, needing to generate ensembles to obtain approximate solutions (Wayand et al., 2013). Moreover, the mesoscale models

demand intensive computing efforts increasing the difficultness coupling to RILEWS (Yáñez-Morroni et al., 2018; Schumacher et al., 2020; Yang et al., 2021). Nowadays, bias correction approaches contribute to reducing the time computing of mesoscale models, improving the estimation of precipitation using in-situ stations (Srivastava et al., 2015; Bannister et al., 2019; Heredia et al., 2018; Jeong & Lee, 2018; Osman et al., 2019; Worku et al., 2020). Nonetheless, the application of corrected mesoscale models in RILEWS in complex topography has not been evaluated.
The object of the present work was to evaluate the implementation of a mesoscale logistic model forced by geomorphological and precipitation constraints. We corrected mesoscale models using weather stations, generating RIL-prone probability zones for the first time in the Southern Andes. The paper is structured as follows: after the introduction, the second section describes the study site and its pertinence to implement RILEWS. In the third section, we describe the data and methods, including the calibration and validation procedures. In the fourth section, we outline the main results of the proposed RILEWS, focusing on the quality of predictors and model outputs. The fifth and final section comprises the discussion and conclusions, presenting the implications of this proposal and their general applicability to the southern Andes.

Modified manuscript:

Rainfall Induced Landslide Early Warning Systems (RILEWS) become a powerful alternative for mitigating human losses and reducing infrastructure damages (Guzzetti et al., 2020; Chikalamo et al., 2020; Hermle et al., 2021). The increase of Rainfall-Induced Landslides (RIL) events showed devastating effects, including loss of human life and destruction of the natural and urban environment (Marjanovi? et al., 2018). Recent RIL affected critical infrastructure and highways in populated areas (Chikalamo et al., 2020; Fustos et al., 2020a; Peruccacci et al., 2017; Fustos et al., 2021). In South America, RIL has caused high social and economic impacts; they require better evaluation in future (Sepulveda & Petley, 2015). The present work evaluates the design of a RILEWS using a mesoscale atmospheric model coupled to a logistic model to mitigate the effect of RIL in the Southern Andes.

Due to new extreme rainfall events related to climate change, RIL events are increasing in the Southern Andes and other parts of the world. To mitigate the impact of extreme precipitation RILEWS have gained interest to mitigate the impact of RIL using different approaches (Peres & Cancelliere, 2014; Tiranti et al., 2014; Sättele et al., 2015; Segoni et al., 2018; Cremonini and Tiranti, 2018; Fan et al., 2019; Tiranti et al., 2019; Thirugnanam et al., 2020; Bernard and Gregoretti, 2021; Lee et al., 2021). RILEWS based on precipitation thresholds shows good agreement but do not consider the effect of soil moisture, leading to bias in their predictive capacity (Marra et al., 2017; Zhao et al., 2019; Chikalamo et al., 2020). Some historical-based RILEWS with long-term observations, climate reanalysis models and atmospheric mesoscale models experiment issues related to the spatial and temporal resolution reducing the performance due to low precipitation accuracy (Lazzari & Piccarreta, 2018; Tichavský et al., 2019).

RILEWS requires accurate precipitation data delivered from local weather stations in dense weather networks, satellite estimations and atmospheric mesoscale models. However, atmospheric mesoscale models showed incapable of representing accurate precipitation fields in areas with complex topography like the Southern Andes (Yáñez-Morroni et al., 2018). Currently, mesoscale models are restricted to the quality of their atmospheric forcings, needing to generate ensembles to obtain approximate solutions (Wayand et al., 2013). Moreover, the mesoscale models demand intensive computational efforts that increase the difficulty of coupling to RILEWS (Yáñez-Morroni et al., 2018; Schumacher et al., 2020; Yang et al., 2021). Recently, mesoscale atmospheric models coupled to local weather stations allow delimitating susceptible to RIL areas means deterministic numerical models (Fustos et al., 2020a). Nowadays, bias correction approaches contribute to reducing the time computing of mesoscale models, improving the estimation of precipitation using in-situ stations (Srivastava et al., 2015; Bannister et al., 2019; Heredia et al., 2018; Jeong & Lee, 2018; Osman et al., 2019; Worku et al., 2020). Therefore, a correct implementation of mesoscale models could allow accurate precipitation in RILEWS. Nonetheless, the application of corrected mesoscale models in RILEWS in complex topography has not been evaluated yet.

The object of the present work was to evaluate the implementation of a RILEWS based on mesoscale atmospheric model coupled to logistic model. We corrected mesoscale models (models that allow represent atmospheric process to synoptic-scale) using weather stations, generating RIL-prone probability zones for the first time in the Southern Andes. The paper is structured as follows: after the introduction, the second section describes the study site and its pertinence to implement RILEWS. In the third section, we describe the data and methods, including the calibration and validation procedures. In the fourth section, we outline the main results of the proposed RILEWS, focusing on the quality of predictors and model outputs. The fifth and final section comprises the discussion and conclusions, presenting the implications of this proposal and their general applicability to the southern Andes.

- Authors should explain that rainfall data are obtained computing rainfall by means of a mesoscale model . The authors should also explain what is it a mesoscale model because the reader could not know it.

  A: We added additional information about the parametrization of the WRF model in section 3.1. We appreciate the comment allowing the reproducibility of our results.

Line 4. “The models were forced by corrected simulations of precipitation and geomorphological features.” Which models?

A: Now we added “logistic” to explain our approach. Thanks

Lines 21 “What is it AUC?

A: Thanks by your observation. Now, we replace

“AUC of 0.80”

To:

Area Under the Curve (AUC) of 0.80

Please considers also the references of Tiranti et al. (2014), Devoli and Tiranti, (2018), Cremonini et al. (2018), Piciullo et al. (2020). Moreover the use of models has also be tested in early warning systems against debris flows (Sattele et al., 2015, Bernard and Gregoretti, 2021).

A: We read the references suggested by the reviewer. Now, we include the references. Thanks for your suggestion.

Lines 90-91 “A database of previous RIL was studied (Gomez-Cardenas & Garrido-Urzua, 2018), divided into calibration subsets with subsequent validation of the method” Unclear sentence

A: We agree. The text were modified:

Original text:

A database of previous RIL was studied (Gomez-Cardenas & Garrido-Urzua, 2018), divided into calibration subsets with subsequent validation of the method.

Modified text:

We used a RIL database (Gomez-Cardenas & Garrido-Urzua, 2018) being separated into calibration sub-database and validation sub-database to evaluate the models' performance.

Line 102 “which allowed represent” poor English form

A: We agree. The text were modified:

Original text:

We used a spatial resolution of 4 km, which allowed represent the complex topography of the Andes.

Modified text:

We used a spatial resolution of 4 km that allows representing the complex topography of the Andes.

Line 107: what is it a mesoscale? Please explain.

A: We agree. The text were modified:

Original text:

> Final Operational Global Analysis product from the US–National Centers for Environmental Prediction NCEP, also known as FNL (NCEP, 2000), was used as the global forcing to obtain the solutions of precipitation at mesoscale.

Modified text:

> Final Operational Global Analysis product from the US–National Centers for Environmental Prediction NCEP, also known as FNL (NCEP, 2000), was used as the global forcing to obtain the solutions of precipitation at 4-km or mesoscale (resolution to an order of kilometres).

Line 119 “corrected simulations of precipitation” substitute it with “modeled and corrected precipitation data”

A: We partially agree. We state that a numerical simulation was carried out to represent the precipitation. We used coarse global atmospheric data. Therefore, we used numerical models instead of data. Our apologies for not being clear. We propose to modify the text:

Original text:

> The logistic regressions were trained based on the local geomorphological conditions (slope) and previously corrected simulations of precipitation.

Modified text:

> The logistic regressions were trained based on the local geomorphological conditions (slope) and previously modelled and corrected precipitation simulations.

Quantities, S, P and E of equations (3) and (4) must be explained in the text.

A: Thanks for your observation. The equations were defined not using the full name of the variables. We modified/clarified the text

Original text:

> The sensitivity was defined as the ratio of true positive predictions of events (TP), over the total of positive events (including false-negative predictions – FN). The specificity was also calculated (Eq. 4) to evaluate the capacity of detection of non-RIL events or true negative (TN), to avoid false positives (FP) (Fawcett, 2006). Finally, this methodology made it possible to evaluate the capacity of each model to detect RIL events (Fustos et al., 2020b).

Modified text:

The sensitivity (S) was defined as the ratio of true positive predictions of events (TP), over the total of positive events (including false-negative predictions – FN). The specificity (E) was also calculated (Eq. 4) to evaluate the capacity of detection of non-RIL events or true negative (TN), to avoid false positives (FP) (Fawcett, 2006). Therefore, this methodology made it possible to evaluate the capacity of each model to detect RIL events (Fustos et al., 2020b).

$$S=TP/(TP+FN) \quad \textbf{(Eq. 3).}$$

$$E=TN/(TN+FP) \quad \textbf{(Eq. 4).}$$

Line 148 Perhaps "Therefore" would better than "Finally"

A: We agree, done.

Lines 156-158 "The stations were compared in the uncorrected simulation showing (~0.26-0.49) to medium (~0.32-0.67) correlation values by Pearson and Spearman coefficients." Unclear sentence

A: Thanks for your observation. The equations were defined not using the full name of the variables. We modified/clarified the text

Original text:

The stations were compared in the uncorrected simulation showing (~0.26-0.49) to medium (~0.32-0.67) correlation values by Pearson and Spearman coefficients.

Modified text:

The uncorrected precipitation simulation showed (~0.26-0.49) to medium (~0.32-0.67) correlation values (Pearson and Spearman) in comparison to in-situ weather stations.

Line 245 "a low uncertainty precipitation representation" should be substituted " "precipitation representation characterized by a low uncertainty"

A: Thanks for your observation. We modified the sentence to : "Therefore, precipitation representation characterized by a low uncertainty in complex topography environments is a valuable contribution"

Line 260 It is "becomes"

A: Modified

Line 262 "The bias-correction using meteolab improved the precipitation representation to compared with weather stations (Figure 4)." Unclear sentence

A: Thanks for your observation. We modified/clarified the text

Original text:

> The bias-correction using meteolab improved the precipitation representation to compared with weather stations (Figure 4).

Modified text:

> From our results, the bias-correction improved the precipitation representation when we compared against the weather stations (Figure 4).

Line 273 “has a complex topography that triggers precipitation events” How topography can trigger a precipitation? Perhaps the complex topography influences…..

A: Thanks for your observation. We corrected/clarified the text

Original text:

> The Southern Andes has a complex topography that triggers precipitation events with different intensities in a few kilometres of separation

Modified text:

> The Southern Andes has a complex topography that influences precipitation events with different intensities in a few kilometres of separation

Line 283 “slope memory approach” what is it? Slope is it relative to the terrain morphology? Please explain

A: Thanks. Now we explain in detail the aim of the sentence. We corrected/clarified the text

Original text:

> The slope memory approach could be the best way to obtain a proxy of the soil moisture content, as there is no network of moisture sensors in the study area.

Modified text:

> In future, the soil moisture memory approach could be the best way to obtain a proxy of the soil moisture content and the slope response to landslides in zones without a network of moisture sensors.

Line 294 “The Andes in one of the most propensity zones to be affected by intense precipitation product of climate change.” Unclear sentence and Lines 294-295 “Moreover, the complex topography needs a high temporal resolution to reproduce the precipitation variability of the Southern Andes.” Meaningless sentence

A: Thanks for your accurate observation. We merge both comments to explain the scientific contribution of our manuscript and their impact on the zone. We modified the two comments:

Original text:

> The Andes in one of the most propensity zones to be affected by intense precipitation product of climate change. Moreover, the complex topography needs a high temporal resolution to reproduce the precipitation variability of the Southern Andes.

Modified text:

> The Andes in one of the most susceptible zones to be affected by intense precipitation changes product of climate change. To reproduce and understand intense precipitation changes and their impact on landslides, a high Spatio-temporal resolution is needed. The present contribution support reproducing accurate precipitation, contributing to robust RILEWS.