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# Comparative analysis of different climate predictions in a temperate zone in France and their impact on slope stability

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Many studies (Cherkaoui, 2015) highlight that climate change impacts the stability of the slopes on the national territory through climatic factors and site factors. Depending on the climatic environment in which the slope is located (mountain zone, coastal zone, temperate zone), these factors do not play the same role and do not have the same influence. We wished to characterize the impact of climate change on the stability of rocky slopes in a temperate zone. The study was conducted in 2 stages: first we evaluate the impact of climate change on pluviometry of 2 sectors located in a temperate zone in France, then we assess the impact of pluviometry changes on slope stability.

## 1 EVALUATION OF THE IMPACT OF CLIMATE CHANGE ON PLUVIOMETRY

First of all, we chose 2 sectors (Mendes and Montsoreau) for which we had rainfall flows for the last 60 years (reference case) and for the next 100 years under the IPCC scenarios described in (van Vuuren & al., 2011). The two scenarios selected for this study are the median scenario (RCP4.5 - Representative Concentration Pathway followed by a figure corresponding to the radiative forcing in W/m<sup>2</sup>) and the strong global warming scenario (RCP8.5). Those scenarios have been simulated with the model WRF Regional Climate Program as part of the EuroCordex program (Jacob & Colette & al., 2013). The results show that the climatic effects modify only slightly the average rainfall flow ( $\pm 10\%$ , depending on the site), but increases the number of days of heavy rain without the maximum intensity of rain being significantly modified (Table 1).

Table 1: Layout of the proceedings

	Number of days where the indicated rainfall threshold is exceeded (days/year)				
Montsoreau	> 1 mm	> 4 mm	> 10 mm	> 20 mm	> 40 mm
HIST (1951-2005)	169	78	20,1	3,2	0,20
RCP4.5 (2007-2100)	168	78,7	22,9	4,2	0,31
RCP4.5 (2050-2010)	169	79,8	24,1	4,6	0,24
RCP8.5 (2007-2100)	168	79,3	24,6	5,1	0,37
RCP8.5 (2050-2100)	168,4	82,2	26,7	5,6	0,30
Mende	> 1 mm	> 4 mm	> 10 mm	> 20 mm	> 40 mm
HIST (1951-2005)	170	97	39,3	8,8	0,67
RCP4.5 (2007-2100)	159	91,3	37,8	9,2	0,95
RCP4.5 (2050-2010)	162	92,8	39,0	9,7	0,96
RCP8.5 (2007-2100)	158	89,3	36,4	9,6	1,04
RCP8.5 (2050-2100)	156	87,5	36,4	10,1	1,30

## 2 IMPACT OF PLUVIOMETRY CHANGES ON SLOPE STABILITY

The hydromechanical behavior of a typical 30 m high slope at the stability limit was then evaluated and compared when subjected to reference case rainfalls or RCP4.5 and RCP8.5 scenarios. For this purpose, we used the UDEC code (Itasca, 2006) which is a 2D numerical modeling program based on the distinct elements method. The fractured slope is represented by blocks that can move and rotate relative to each other. The rock-mass is crossed by two families of fractures whose orientations are chosen so that the slope is close to its limit of stability. Over-fracturing, simulating rock-mass degradation, is added in an area 12 m wide along the slope. The model simulates the gradual degradation of fractures subjected to a shear force from an initial angle to a residual angle (the progressive "scrubbing" of the asperities of the fracture plane). It also simulates the fluid flow through the fracture network (the blocks are assumed to be impermeable), as well as the impact of the fluid pressure on the mechanical behavior of the slope.

The results show that the effect of an increase in the average infiltration rate has no impact on slope stability. This is explained by the fact that the pressures induced by average rainfall flow rates remain very low ( $< 1$  Pa) compared with normal stress values on fractures ( $> 100$  Pa). If a sufficiently high infiltration rate is imposed, a mechanical impact may appear for a slope initially "in

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limit of stability" (Figures 1), without this necessarily resulting in additional instabilities. Given the increase in the number of rainy days for RCP4.5 and RCP8.5, we conclude that climate change may impact rocky slopes in temperate zone.

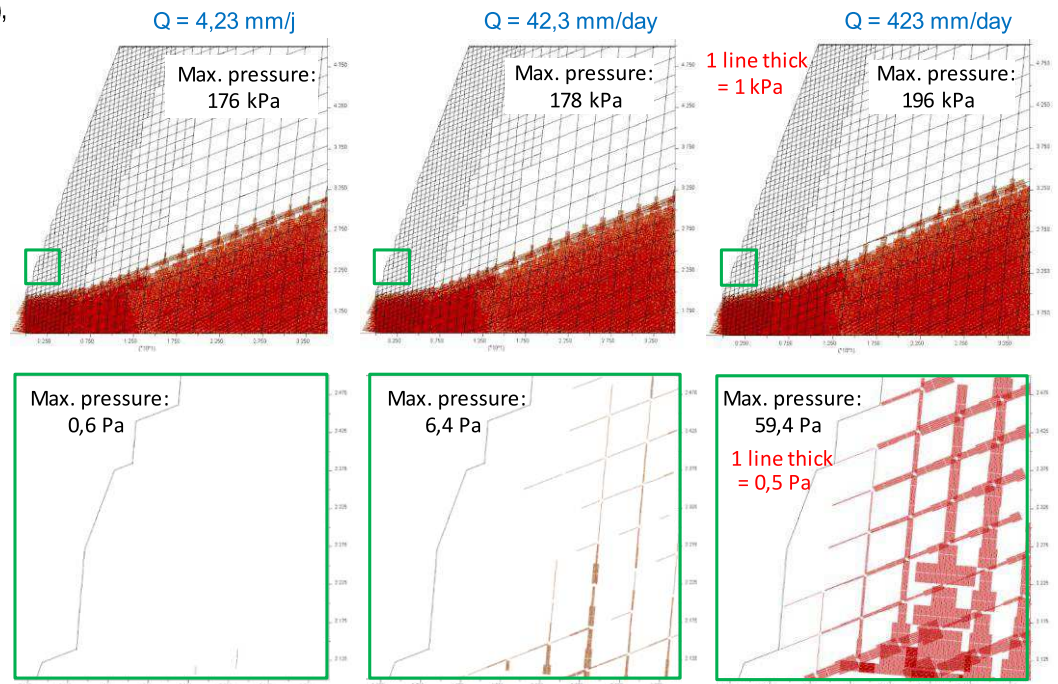


Figure 1: Water pressure in fractures according to rainfall: (a) 4.23 mm / day; (b) 42.3 mm / day; (c) 423 mm / day (The 3 bottom outputs are a zoom located at the base of the slope (green square). The 3 top outputs (respectively the 3 bottom outputs) were made considering the same pressure scale. The maximum pressure is the maximum pressure computed inside the window considered)

### 3 CONCLUSION

Given the increase in the number of rainy days for RCP4.5 and RCP8.5, we conclude that climate change may impact rocky slopes in temperate zone. To go further, we plan to evaluate the impact of the fracture network geometry / connectivity on the evolution of the slope foot pressures and the effect of this evolution on the mechanical stability of the slope. We also plan to take better account of transient effects and the change over time of the hydromechanical characteristics of fractures to simulate leaching of the filling of initially clogged fractures.

### 4 ACKNOWLEDGEMENTS

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