

# **DAMOCLES PROJECT WORK**

**Contract No EVG1 - CT-1999-00007**

Instituto Pirenaico de Ecología, CSIC, Spain  
Report for the Fifth Progress Meeting: Field and Laboratory activities

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## REPORT FOR FIFTH PROGRESS MEETING

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### **Summary**

During the period May-November 2002 the group from the Pyrenean Institute of Ecology has worked especially on the relationships between extreme rainfall events and occurrence of debris flows in the Flysch Sector of the Central Pyrenees, trying to locate this occurrence in the context of the most common equations (those from Caine and Innes). These equations establish thresholds of debris flow triggering according to the intensity and duration of precipitation. Previously a map of the spatial distribution of infrequent rainfall events was constructed for different return periods. It is interesting to note that the higher intensity events recorded in the Flysch Sector are located in an intermediate position. The results obtained confirm the extreme uncertainty in the climatic factors explaining the occurrence of debris flows. Secondly, two reports have been made comparing i) the characteristics of debris flows in the Alps and in the Pyrenees, and ii) the models used by the Italian and Spanish groups to construct debris flow susceptibility maps. The logistic model used up to now to relate the possible spatial triggering of debris flows and their respective runouts has been improved. Finally, information requested on various characteristics of the Ijuez catchments has been sent to the Newcastle's group. Several papers have been sent to international journals and presented in oral form in meetings.

### **Section 1. Objectives of the reporting period**

During the period May-November 2002 these have been the objectives of the IPE's group:

i) To construct a map (or maps) with the spatial distribution of infrequent rainstorm events. Calculations had to be made for different return periods.

ii) To locate the occurrence of debris flows in the Pyrenees within the context of most common equations calculated to relate debris flow triggering and the rainfall intensity-duration.

iii) To compare the debris flow characteristics and relationships in the Alps and in the Spanish Pyrenees.

iv) To compare the methods used by the Italian and Spanish groups to construct debris flow susceptibility maps.

v) To improve the logistic model to accurately forecast not only the areas where debris flow will occur, but especially the areas affected by debris flow tongues and runouts.

vi) To send the requested information to the Newcastle's group in order to modelize the debris flow occurrence in the Ijuez catchment.

vii) To prepare papers and presentations for international journals and meetings. A book showing the results obtained in the Spanish Pyrenees is in progress.

## **Section 2: Scientific progress made in different work packages**

### *Workpackage 1*

#### A) Regional modelling of extreme rainfalls

One of the main efforts during this period of the DAMOCLES project has been to construct a map showing the distribution of extreme rainfalls hazard in the study area (central Spanish Pyrenees). A set of maximum expected daily rainfall maps has been produced, for return periods of 1, 5, 25 and 100 years. The method used is based on standard frequency analysis.

The data have been collected from 37 climatic stations in the Pyrenees, for the period 1941-2000 (60 years). A correction procedure has been applied to the parameters derived from series not covering the entire period.

A censored sample has been collected from the series, taking all the events exceeding the 97th centile of the distribution. This procedure is commonly known as 'peaks over threshold' or 'partial duration series' sampling, and permits to extract the information concerning only the right tail of the distribution of rainfall. The L moments diagram (Fig. 1) has been used to select the distribution better fitting the data. Among five commonly used three-parametric, and two bi-parametric functions, the Generalized Pareto distribution appears clearly as the best model.

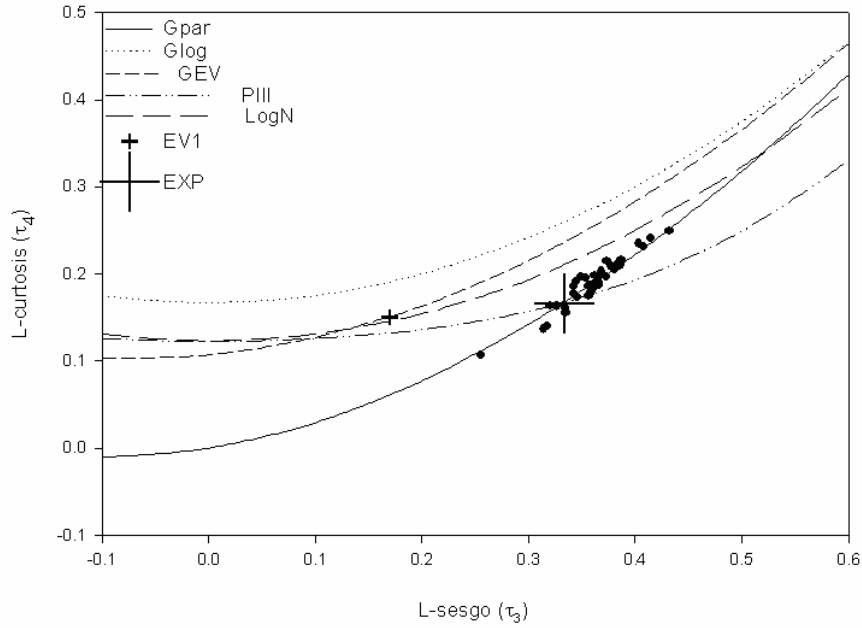


Figure 1. L moments diagram, showing the agreement between the observed series and the Generalized Pareto model (Gpar).

The Generalized Pareto distribution function has the following form:

$$F(x \geq X) = 1 - \left[ 1 - \frac{\mathbf{k}}{\mathbf{a}} \cdot (x - \mathbf{b}) \right]^{\frac{1}{\mathbf{k}}}$$

where  $\mathbf{b}$ ,  $\mathbf{a}$  and  $\mathbf{k}$  are location, scale and shape parameters, respectively.

For constructing a continuous map of extreme rainfall, even in locations where no data exist, a regional approach to frequency modelling has been adopted. The regional hypothesis, validated in many studies, states that the shape of the frequency distribution of extreme rainfalls does not varies within a given climatic region. So, a regional shape parameter can be computed integrating the information of all the observatories in the region (what reduces uncertainty), and only the scale and location parameters need to be estimated locally.

After calculating the regional shape parameter, the other two parameters have been modelled by multiple linear regression upon several topographical variables, at different scales. The resulting models are quite good, with  $r$  squares of 0.864 for the location parameter and 0.775 for the scale parameter. Both parameters exhibit a good agreement with the regional averaged altitude, but a different spatial trend.

The distribution of the location parameter is shown in Fig. 2. The distribution of  $\mathbf{b}$  shows, in general, an increase from SW to NE, slightly corrected by the distribution of the relief. Thus, the lowest values are located in the centre of the Inner Depression, and progressively increase toward the upper part of the Aragon Valley. The parameter of origin is strongly related to the distribution of mean precipitation.

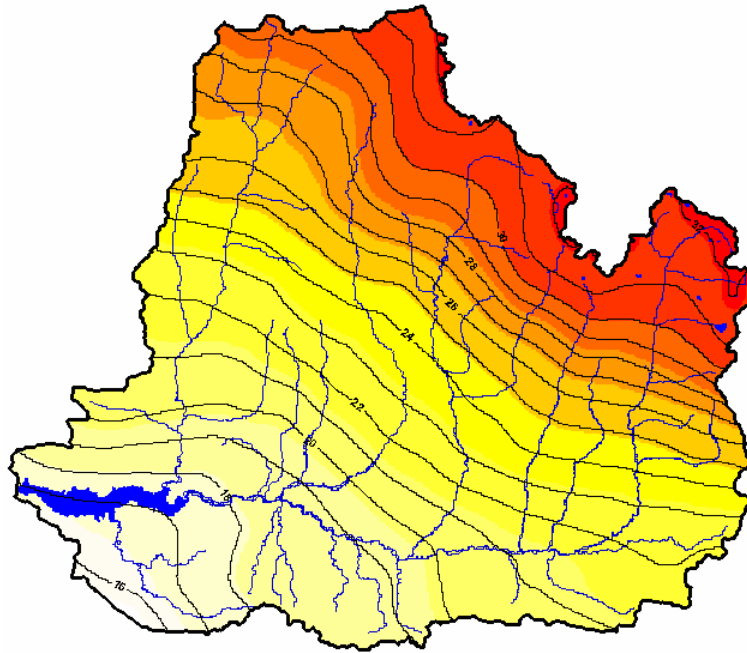


Figure 2. Distribution of the location parameter (*b*).

The distribution of the scale parameter is shown in Fig. 3. The distribution of *a* in the study area shows, in general, a gradation from SE to NE conditioned at the same time by the distribution of the relief and the Oceanic-Mediterranean climatic transition. Thus, the lowest values of *a* appear in the western part of the Pre-Pyrenees and the Inner Depression, and the highest ones in the Inner Sierras and the Axial Pyrenees. The maximum values are obtained around the Aspe and Collarada massifs.

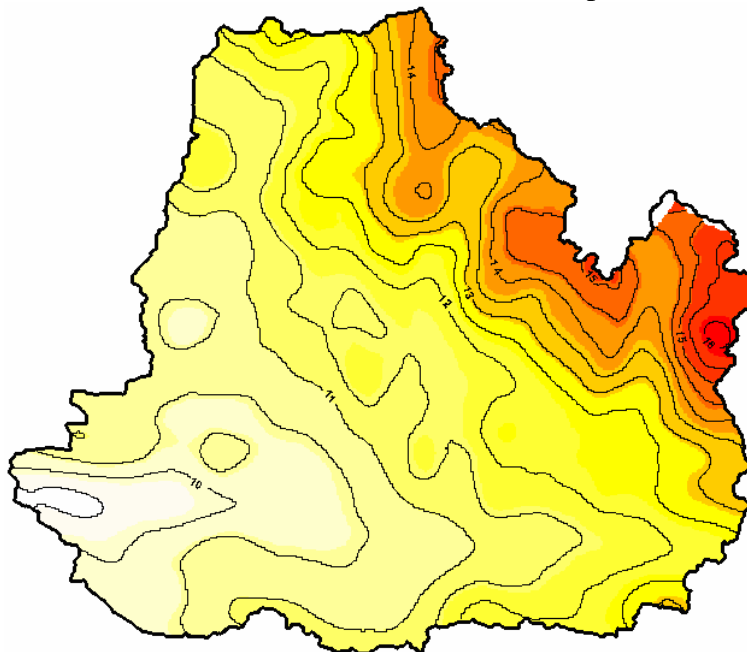


Figure 3. Distribution of the scale parameter (*a*).

A final map at 1:100 000 scale has been produced, showing the distribution of both parameters in the study area. Along with the regional shape parameter, it permits to construct magnitude / frequency curves for any location on the study area, even if no instrumental data are available. Also, four different maps have been produced, showing the distribution of the maximum expected daily precipitation in the study area for a return period of 1, 5, 25 and 100 years.

#### B) Rainfall intensity/debris flow occurrence relationships

In most of cases, the triggering of debris flows is caused by an increase of pore pressures provoked by a high supply of water into the soil, whether due to rainfall or to snowmelt. In some cases, other processes, like earthquakes, volcanic eruptions or other mass movements can play an important role, but soil saturation by water is recognized as the main cause of debris flow triggering. The persistence of moderate intensity rainfalls during several days can cause the saturation of the soil and debris, favouring the mass movement. In other cases, the development of debris flows is related to the occurrence of short-duration, highly intense rainfalls.

The assessment of the main causes of observed debris flows is also related to the question of the timing or recurrence time of the process, which is another crucial question. Assigning the hazardous process a time dimension is not only an interesting theoretical question; it is completely necessary in making risk assessments, since any given occurrence probability must be referred to a time interval.

Assessing the timing of debris flows is not an easy task. Several authors have related the occurrence of one or more debris flows to specific rainstorms or rainfall periods, but normally the researcher has no idea of the exact moment of the debris flow triggering, and he has to deal with conjectures or approximations. In the case of the Spanish Pyrenees, the Ijuez catchment (54.6 km<sup>2</sup>) has been selected for a detailed assessment of the recurrence of debris flows. A sequential cartography of debris flows has been made, using the aerial photographs of 1956, 1977 and 1990. The map of debris flows has been completed in 2001 by a field recognition of debris flows.

Fig. 4 shows (black dots) the cumulative number of debris flows observed in different moments. A linear disposition of the dots can be clearly seen, and demonstrated by the high coefficient of determination of the adjusted line ( $r^2 = 0.997$ ). The high linear trend on the occurrence of debris flows demonstrates that, far from being a rare phenomena, the triggering of shallow landslides in the area is a relatively common and constant process in the Ijuez catchment (and, most probably, in the Flysch Sector of the Spanish Pyrenees). The slightly lower than expected number of debris flows mapped in 2001 can be attributed to the change in the methodology, as field recognition mapping is less exhaustive than aerial photo analysis. The mean rate

of occurrence is 3.4 debris flows per year, what makes a relative value of 0.06 debris flows  $\text{km}^{-2} \text{yr}^{-1}$ . Considering this figures, shallow landsliding is a very frequent process in the Flysch Sector of the Spanish Pyrenees.

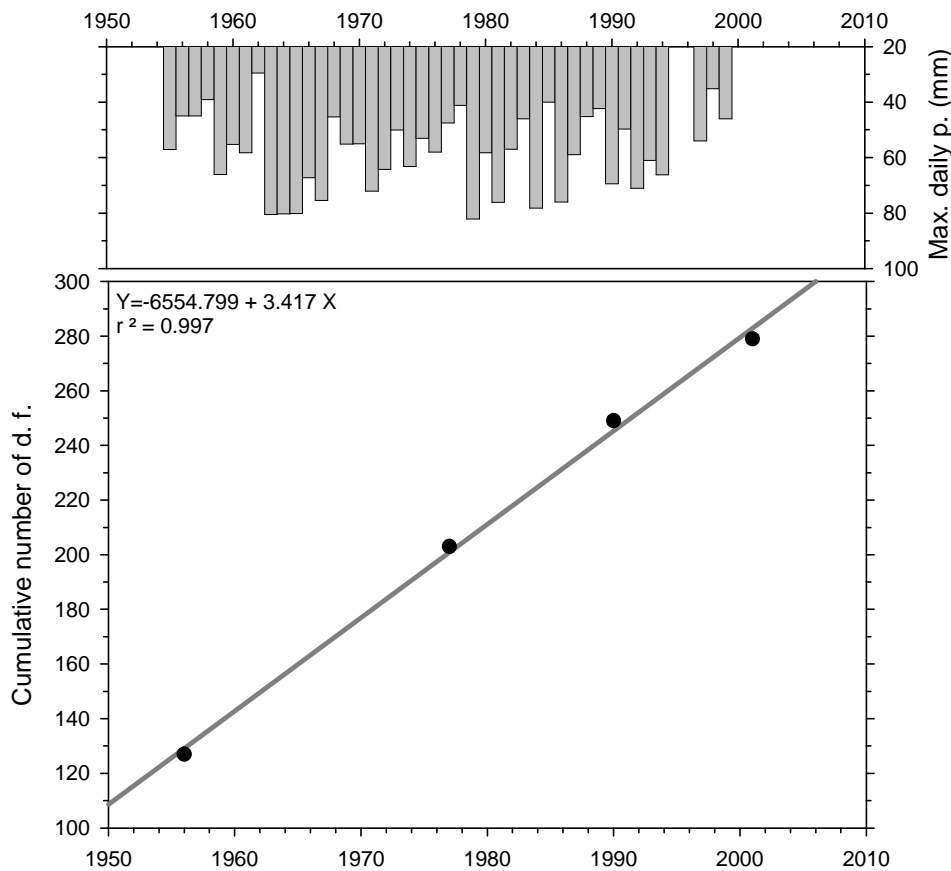


Figure 4. Cumulative number of debris flows in the Garcipollera valley, and annual maximum precipitation series at Bescós station

The analysis of the sequential aerial photos has also confirmed the important changes in land cover that occurred after farmland abandonment of the Ijuez catchment and the human-induced reforestation during the fifties. It is noticeable that, despite the great changes in land cover, the timing of debris flow occurrence does not show any change. This lessens the effectiveness of reforestation as a debris flow mitigation practice in the area, and enhances the importance of other factors like topography or soils.

No information exists in the area about the exact timing of the different debris flows, so to relate them to specific events is a hard and very uncertain task. Fig. 4 also presents information on the series of annual maximum precipitation recorded in the Ijuez catchment ('Bescós de la Garcipollera' weather station). Snowmelt is a very marginal runoff producer process in the area, so rainfall is likely to be the main cause for shallow landsliding. The series of extreme events does not show any trend in the period 1955-1999. Rainfalls exceeding 45-50 mm in one day are relatively frequent,

the absolute maximum recorded being 82.5 mm. Considering the high regularity in the occurrence of debris flows, even during the last and shortest sampling period (1990-2001), it can be concluded that the triggering of shallow landslides in the Ijuez Valley is related to relatively frequent extreme precipitations, having a recurrence of no more than 2 to 5 years. The corresponding quantiles, calculated using the Generalized Pareto distribution and probability weighted moments for parameter estimation, are 36.8 and 46.6 mm, respectively.

This leads naturally to the question of the existence of rainfall thresholds for the triggering of debris flows. The hypothesis of the existence of a critical depth / duration has been investigated by many authors, and several empirical thresholds have been proposed. Caine (1980), based in 73 published observations of rainfall intensities and durations that have caused debris flow activity, proposed the following limit curve:

$$I_{cr} = 14.82 t^{0.61}$$

where  $I_{cr}$  is the critical rainfall amount (mm) above which debris flow are likely to occur, and  $t$  is rainfall duration (h). The equation is an envelope of limiting curve: below it a given precipitation event is not likely to provoke a debris flow, but above it debris flow will occur only under favourable conditions. In most areas, the rainfall intensity has to be higher than the proposed by the curve to provoke landsliding. Innes (1983), from a similar bibliographic survey, outlines a curve that differs greatly from that of Caine:

$$I_{cr} = 4.9355 t^{0.5041}$$

The divergence between both curves implies the great uncertainty that already exists about the existence of universal thresholds in geomorphic processes.

Fig. 5 shows the threshold curves proposed by Caine and Innes, along with empirical data from the Ijuez Valley. These empirical data are shown both as the observed annual maximums (black dots) and the adjusted depth / duration / recurrence curves (black lines). The observed extreme rainfalls are located significantly below the Caine limiting curve. that corresponds to precipitations of 200 to 500 years recurrence in the area. The curve from Innes is much more reliable. The estimated return period for rainfall events triggering landslides in the Ijuez Valley (2-5 years) is not very far from the Innes threshold curve. This situates the Ijuez Valley among the most susceptible areas for debris flows reported in the literature.



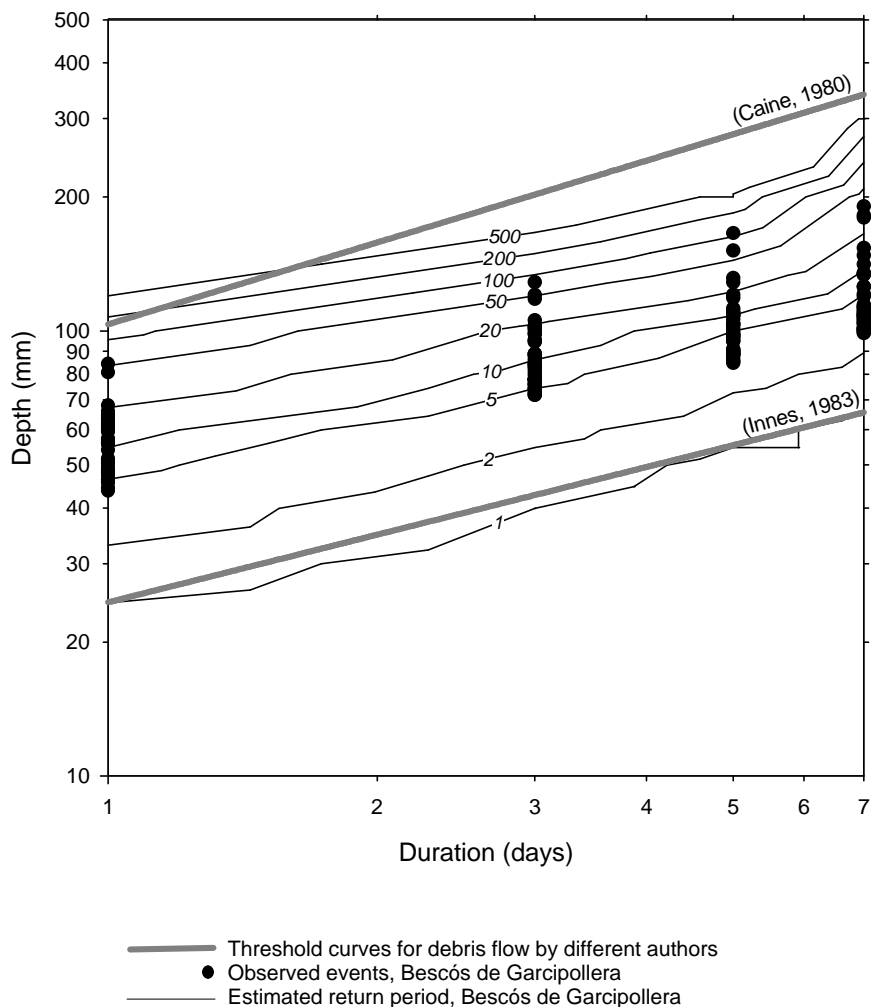


Figure 5. Precipitation depth / duration / recurrence curves and observed extreme events at Bescós station, 1955-1999, and theoretical debris flow triggering threshold curves by different authors

### C) Comparison of debris flow characteristics and relationships between the Alps and the Pyrenees

One of the deliverables expected within the DAMOCLES Project is a comparison between the empirical relationships for debris flows in the Alps and in the Spanish Pyrenees. This comparison has been made in spite of the large differences that exist between both types of debris flows. It is very important to take into account that debris flows studied in the Alps correspond to valley-confined debris flows (Brunsdén, 1979), whereas those studied in the Spanish Pyrenees correspond to hillslope or unconfined debris flows. This is a problem to establish comparisons, since the valley-confined debris flows mainly depend on the availability of sediment in the channels or the immediate taluses. Nevertheless, there are some points of accordance:

- The volume of the debris flow is a relatively important characteristic in determining the length and runout of the debris flow, especially in the Alps.

- The size (or volume) of any future debris flow is extremely difficult to assess, and then a very high uncertainty is always present in any predictive study. In fact, Rickenmann (1999) points out that debris flows are a too much complex geomorphological (and hydrological) process, and for this reason numerical simulation is still very difficult to use for practical applications.

In general, there are many difficulties to compare valley-confined and unconfined debris flows. Fig. 6, for example, plots the total length of debris flows vs. potential energy ( $M H$  factor) including the results from the Spanish Pyrenees and the Rickenmann (1999) relationship. The differences are obvious because the adjusted power function from Rickenmann is clearly over that from the Pyrenean debris flows. That means that, according to the Rickenmann equation, with the same volume of debris the valley-confined debris flows undergo a larger displacement than unconfined, Pyrenean debris flows.

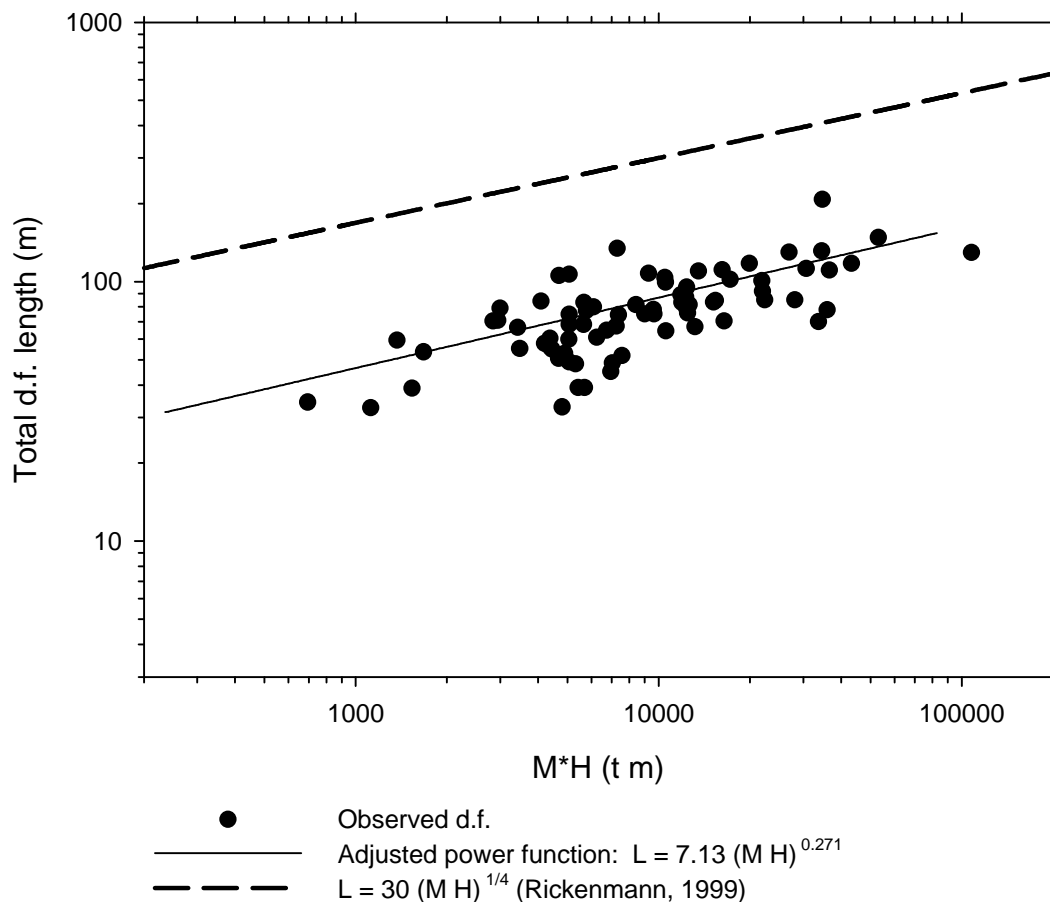


Figure 6. Plot of the total length of debris flow vs. the available potential energy (represented by the  $M H$  factor). The adjusted power function is also represented, along with the Rickenmann (1999) relationship.

Nevertheless, when the debris flow deposit length is plotted vs. the total volume, no especial differences can be found between the Alpine (Crosta, 2001) and the Pyrenean debris flows (our results). Fig. 7 shows that the Rickenmann's (1999) adjusted theoretical function is again over the empirical functions, and that the Alpine and Pyrenean debris flows are relatively close one to the other. For the Pyrenean debris flows the adjusted power curve has the form:

$$L_f = 4.98 V^{0.294}$$

where  $L_f$  is the length of the deposit (m) and  $V$  its volume ( $m^3$ ).

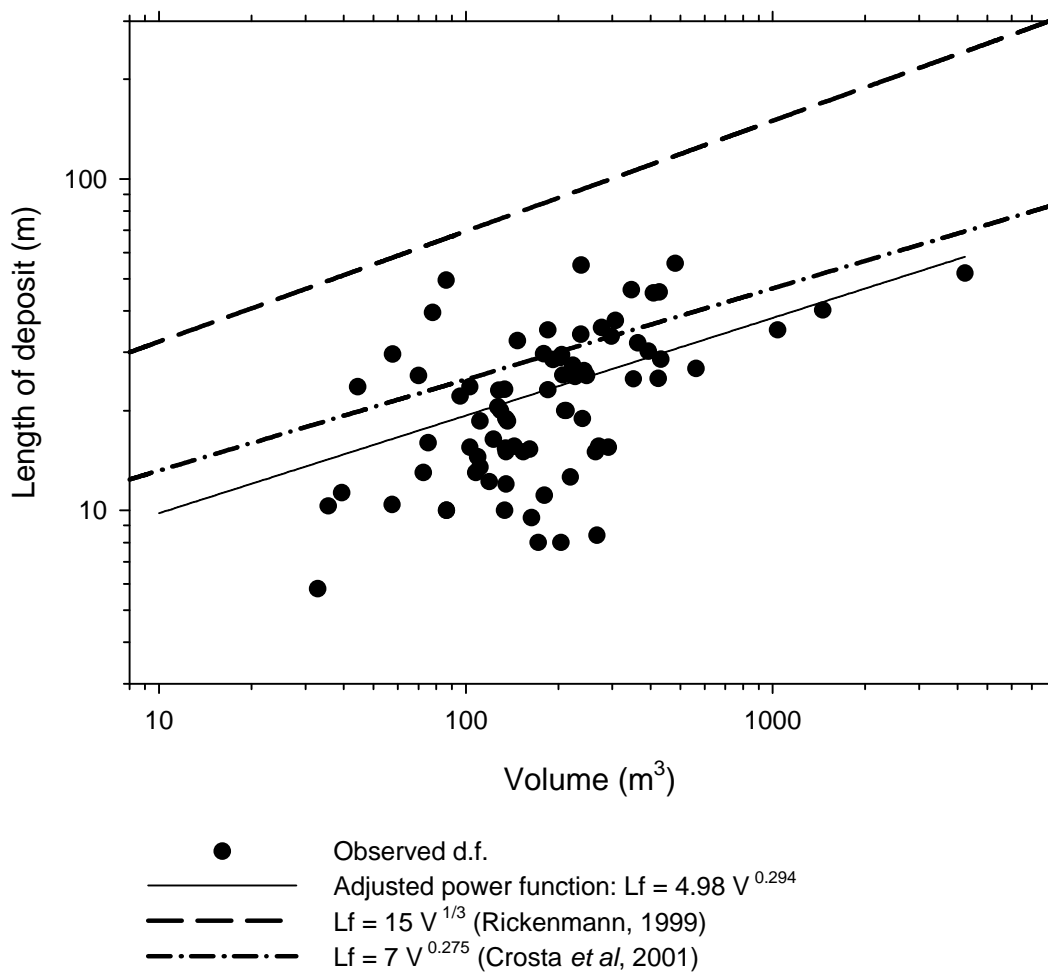


Figure 7. Plot of the debris flow deposit length vs. the total volume, along with the adjusted power function and the relationships by Rickenmann (1999) and Crosta *et al.* (2002).

This expression is very similar to that of Crosta *et al.* (2001), also shown in Fig. 7. It is interesting, however, to note that the Pyrenean debris flows produce an adjusted power function located slightly below that from the Alpine Debris flows,

confirming that confined debris flows are able to travel further than unconfined debris flows.

#### *Workpackage 4*

##### A) Model implementation

Statistical models are based on contiguity analysis of the observed landslides and a set of variables that can potentially be considered instability factors. Statistical approaches are data-based, and make use of the information provided by past slope failures to predict future ones. In a previous stage of the DAMOCLES project, a statistical model based on multivariate logistic regression was developed for the Garcipollera valley (Central Spanish Pyrenees). In the last months a methodological revision has been carried out in order to solve some problems arising from the scarcity of observed events.

In statistical landslide hazard assessment methods, the dependent variable is normally coded as a dummy or binary variable. As landsliding is normally a rare event, the population can have hundreds or even thousands of times fewer events (ones) than non-events (zeros). This is specially true in grid or raster based models, but is also frequent in spatially lumped ones (based on unique condition or landform units). It is well known that common statistical multivariate procedures, such as discriminant analysis and logistic regression, are designed to work with groups that are more or less equal in size. When dealing with rare events, like landslides, the groups tend to be very unequal, and the models tend to sharply underpredict the probability of rare events. This was the case for the Garcipollera valley model, where the pixels with debris flow represented 2.5 in 10 000 cases.

A very similar problem has been analysed by King and Zeng (2001). They propose a design based in endogenous stratified sampling, or sampling within categories of the dependent variable. The strategy is to select all the cases for which ( $Y=1$ ) and a random selection of cases for which ( $Y=0$ ). This sampling procedure is specially useful when, as is the case of landslide inventory, the researcher knows the exact proportion of ones in the population (prior knowledge). The number of zeros to collect is a decision of the researcher. A number of zeros ten times higher than ones has been used for the Garcipollera valley model.

The endogenous stratified sampling procedure requires correcting the estimated probabilities based on the prior information about the proportion of ones in the population. Derived from the work of King and Zeng (2001), the following correction has been used:

$$p' = p \cdot \exp\left(\frac{1-t}{t} \cdot \frac{y}{1-y}\right)$$

$p'$  being the corrected or posterior probability,  $p$  the estimated probability,  $t$  the proportion of ones in the population or prior probability, and  $y$  the proportion of ones in the sample or sampling probability.

Exogenous sampling prior correction was probably first used by Prentice and Pyke (1979). Other correction procedure available for exogenous sampling is the weighting maximum-likelihood estimator formulated by Manski and Lerman (1977). For the Garcipollera valley model the former procedure has been selected due to its ease of use.

An extensive explanation of the model is reported in a separate report, as a deliverable of the DAMOCLES project.

#### B) A review of statistical hazard models

A review of debris flow hazard mapping by multivariate statistics has been written, as a deliverable of the project. The main assumption of statistical hazard models is that landsliding will occur under the same conditions as in the past, so the study of the observed, past landslides will permit to develop models predicting the occurrence of landslides in the future.

Different multivariate statistical methods can be used for landslide modelling, like linear regression, discriminant analysis or logistic regression. Each method has its own peculiarities, but are very similar in practice. The main difference can be addressed between procedures based on multiple linear regression and classification approaches like discriminant analysis. In linear regression, the dependent variable is continuous (density of debris flows, for example), whereas in classification procedures the variable must be categorical (instability groups). As normally there are only two categories (stable or landslide-free and unstable), the logistic regression can be used as well.

The main difference between statistical models lies in the selection of the mapping unit. It is not a trivial question, as could be considered at a first sight, and it has important conceptual and practical implications. Mapping units are portions of the land surface that are considered homogeneous, and are assigned a unique hazard value, so they are the minimum meaningful spatial units in the analysis. This refers directly to the consideration of space in the model. Basically, there are two approaches: spatially distributed and spatially lumped models.

Approaches based in raster maps or grids lie into the first group. The grid format works specially well with continuous, spatially distributed variables, like altitude, slope, or drainage area. Categorical variables like vegetation or lithology can

be represented in a grid as well. Grid approaches to hazard modelling allow also to consider hazard as a continuous and distributed variable, too, what is more realistic than delimitating regions of risk (see Fig. 8). Grid based approaches also present the advantage of a much greater resolution than lumped models.

A problem with grid based statistical models can be the very high number of cells that must be entered in the model. This problem, however, is being minimised with the development of modern computers, that allow multivariate calculations with hundreds of thousands data. Furthermore, the exogenous sampling method previously outlined, permits to reduce the sample in various orders of magnitude.

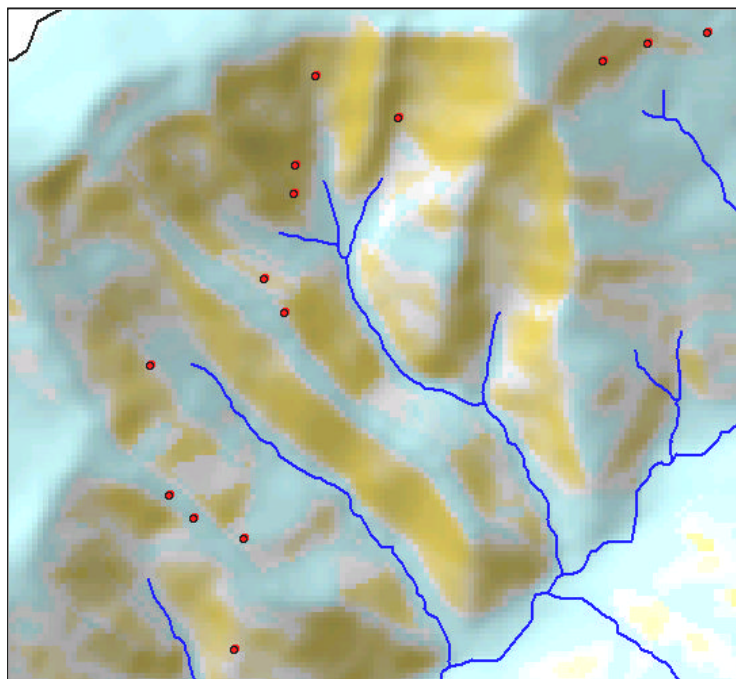


Figure 8. Grid or raster-based hazard map. The red dots show the location of observed debris flow scars.

Spatially lumped models, on the other hand, are based in the aggregation of the land surface into discrete units, whether based on the distribution of thematic layers (unique condition units) or exclusively on the morphology of the terrain (terrain units, slope and topographical units, for example). Evidently, this dramatically reduces the spatial resolution of the final maps, what can be considered one of the main drawbacks of the procedure. However, land units work specially well with medium to big mass movements. This kind of processes are not adequately represented in a grid, where the landslide would be partitioned in a big number of cells. Those cells would be treated as random independent variables, what is not the case; evidently, the cells that belong to the same mass movement must be considered as the same thing. The partitioning of the land surface into landform units partially

solve this problem, as in this kind of movements are normally entire slopes what fail, and not small parts of them as in the case of small debris flows or soil slips. Landform units have, thus, a certain physical meaning in relation to big landslides. Figure 9 is an example of a slope units-based debris flow hazard map. As can be seen, slope units can be adequate to the modelling of big (rotational) landslides, but are much less indicated in the case of shallow debris flows. The loss in resolution is also evident in the figure. It can be seen that hazard can not yet be considered a spatially distributed variable, as it is assigned to the entire slopes. The map reader can perhaps know the probability of finding a slope failure (or a number of them) within a given slope, but has no information about which part of the slope is more likely to be affected.

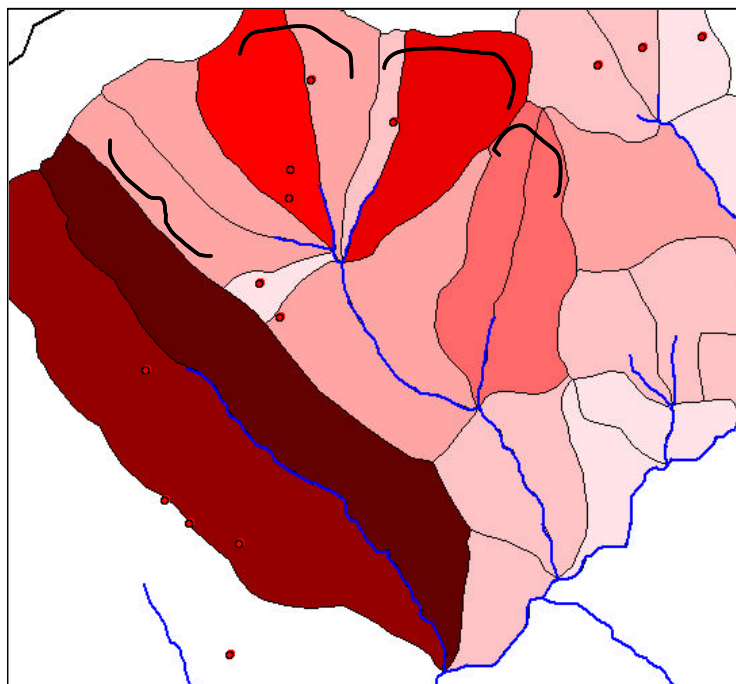


Figure 9. Slope units-based hazard map. The red dots show the location of observed debris flows, and the black lines the scars of rotational landslides.

The selection among grid based and spatially lumped models yields also practical and methodological implications. Land units do not work well with continuous variables. In a unique conditions approach, continuous variables must be categorised, according preferably to a previous exploratory analysis. In a landform units approach, continuous variables can only be treated by statistics describing the distribution of the variable within the land unit. Reducing a continuous variable to a discrete or categorical scale, or to a statistic, implies a great loss of information.

Another pitfall of lumped models, specially in a classification context (discriminant analysis and logistic regression) is the need to categorise also the dependent variable. The researcher has to decide whether a given land unit is stable or

not, based on the density of debris flows or the percent area occupied by landslides. This implies again a loss of information, and introduces a certain level of subjectivity in the process of hazard modelling. In this case, it seems better to use a multiple linear regression on the relative quantity of land movements in the unit, what is a continuous quantity.

Both the distributed and lumped approaches have their own advantages and drawbacks. A distributed approach may seem better due to its higher resolution and its spatially continuous character. A grid based model, however, poses many problems on modelling big movements, like rotational landslides. In this last case, a physically meaningful lumping approach seems to be preferable to a grid.

### C) Collaboration with other DAMOCLES's groups

Information from the Newcastle's group on modelization of monthly runoff in the Ijuez catchment has been discussed. Comments have been sent to the Newcastle group.

*Cost statements (Euro currency)*

#### **Year 1 (March 2000-March 2001)**

##### Personnel and Overheads

a) DAMOCLES proposal				
Staff Cat.	Hours	Personnel Costs	Overhead costs	
1	1300	46800	45396	
2	350	5950	5771	
4		10133	0	
<b>Total</b>		<b>62883</b>	<b>51167</b>	

b) Real costs				
Staff Cat.	Name	Hours	Personnel amount	Overhead amount
1	García Ruiz, J.M.	600	21600.38	20951.28
1	Martí Bono, C.	600	21600.38	20951.28
1	Valero Garcés, B.	100	3600.06	3491.88
2	Errea Abad, M.P.	350	5950.92	5772.12
4	Seeger, M.	600	4237.14	0
4	López Moreno, J.I.	1000	6376.74	0
4	Lorente Grima, A.	250	2288.35	0
4	González Sampériz, P.	250	1798.53	0
<b>Total</b>			<b>67452.50</b>	<b>51166.56</b>

The overhead amount was coincident with the foreseen, the total personnel amount exceeded the budget in Staff Category 4.

##### Consummables costs

a) DAMOCLES proposal.....	4500
b) Real costs.....	2138.96



	Travel and subsistence	
a) DAMOCLES proposal		
	Project meetings.....	4500
	Field work.....	3200
b) Real costs		
	Project meetings.....	1580,20
	Field work.....	2308.73

**Year 2 (March 2001-February 2002)**

Personnel and Overheads

a) DAMOCLES proposal				
Staff Cat.	Hours	Personnel Costs	Overhead costs	
1	1469	53.942	52.326	
2	400	6.936	6.728	
4		10.133	0	
Total		71.011	59.052	
b) Real costs				
Staff Cat.	Name	Hours	Personnel amount	Overhead amount
1	García Ruiz, J.M.	600	22.032	21.372
1	Martí Bono, C.	600	22.032	21.372
1	Valero Garcés, B.	269	9.877,68	9.581,78
2	Errea Abad, M.P.	400	6.936	6.728
4	Lorente Grima, A.	1062	9.621.72	0
4	González Sampériz, P.	875	6.728.75	0
Total			77.228,15	59.053,78

Consumables costs

a) DAMOCLES proposal.....	3250
b) Real costs .....	3411.95

Travel and subsistence

a) DAMOCLES proposal		
	Project meetings .....	3500
	Field work .....	3200
	Total.....	6.700
b) Real costs		
	Project meetings and Field work .....	10.854,03

**MANPOWER USED DURING YEAR 2**

(In man months)

	WP1	WP2	WP3	WP4	WP5	TOTAL
García Ruiz	4		1			5
Martí Bono	4				1	5

Valero Garcés	2		2
Errea Abad	3.5		3.5
Lorente Grima	6.5	2	8.5
González Sampérez	7		7
<b>TOTAL</b>	<b>27</b>	<b>3</b>	<b>31</b>

### Year 3 (March 2002-September 2002)

#### Personnel and overheads

##### a) DAMOCLES proposal (all year)

Staff Cat.	Hours	Personnel Costs	Overhead costs
1	1306	48.910	47443
2	274	4.847	4.702

##### b) Real costs

Staff Cat.	Name	Hours	Personnel Costs	Overhead costs
1	García Ruiz, J.M	350	13.107,5	12.714,27
1	Martí Bono, C.	300	11.235	10.897,95
1	Valero Garcés, B.	150	5.617,50	5.448,98
2	Errea Abad, M.P	200	3.538	3.431,86
<b>Total Costs</b>			<b>33.498</b>	<b>32.493,06</b>

#### Consumables costs

a) DAMOCLES proposal.....	6.939,65
b) Real costs.....	1.388,74

#### Travel and subsistence

a) DAMOCLES, proposal.....	9.859,95
c) Real costs.....	
Project meetings and field work.....	2.302,90

### MANPOWER USED DURING YEAR 3 (April-September)

	WP1	WP2	WP3	WP4	WP5	TOTAL
García Ruiz	1.3				1.5	2.8
Martí Bono	0.5				2	2.5
Valero Garcés	0.2				1	1.2
Errea Abad	0.6				1	1.6
<b>TOTAL</b>	<b>2.6</b>				<b>5.5</b>	<b>8.1</b>

### **Section 3. Milestones and deliverables obtained**

During the last six months the following milestones and deliverables have been obtained:

- Final improvement of a debris flow model to forecast the areas affected by the occurrence of debris flows according to the debris flow susceptibility map and the length of runout.
- Maps of spatial distribution of infrequent rainstorm events and their corresponding return period.
- A report comparing the relationships between the Alpine and the Pyrenean debris flows.
- A report comparing the methods to construct debris flow susceptibility maps between the Italian and the Spanish groups.

### **Section 4: Deviations from the Work Plan and/or time schedule**

No deviations have been observed from the Work Plan. All the deliverables foreseen in our workpackages have been already sent to the Coordinator and included into the web page, or are adequately in progress. The comparison of debris flow relationships between Alpine and Pyrenean debris flows has been affected by some delay but now is finished.

### **Section 5. Coordination of information between partners and communication activities**

We have no coordination problems both with the General Coordinator of the Project and with the other groups.

The IPE's group organised a Workshop on debris flow mapping and forecasting at Zaragoza in May, 2002, with the attendance of several members of the DAMOCLES Project as well as end-users and other interested persons (coming especially from the University). Three persons of the IPE's group will attend the GISIG meeting.

Members of the IPE's group have participated in different meetings, presenting results from the DAMOCLES Project:

- International Workshop on Paleofloods, Historical data and Climate Variability. Barcelona, 16-19 October, 2002.
- 7th National Meeting on Climatology, Albarracín, 27-29 October, 2002.
- XXVIIth General Assembly of the European Geophysical Union. Niza, 22-26 April, 2002.

## **Section 6. Difficulties encountered at management and coordination level**

No difficulties have been found at management and coordination level.

## **Section 7. Plan and objectives for the next period**

During the next period (November 2002-February 2003) the work plan of the IPE's group is the following:

i) To map the areas directly affected by debris flow occurrence, by crossing the information from the landslide susceptibility map and from the debris flow relationships. A first, successful attempt was made in the Ijuez catchment, but now is being enlarged to the whole Flysch Sector.

ii) Santiago Begueria will deliver his PhD Thesis in January 2003 at the University of Saragossa on "sediment sources using different methodological approaches", and including a part related to the role of debris flows as sediment sources.

iii) To attend the GISIG meeting at Milan in November 2002.

iv) To prepare papers for international journals and conferences. The IPE's group will attend the meeting on "Water Resources" at Kyoto (March 2003) and the next EGS Assembly at Nice (April 2003). There is quite (spatial, methodological) information to prepare papers for international journals in the next few months.

v) To write the final Project Report in January-February, 2003)

vi) To write a book including the main results from the IPE's group, in order to provide a global perspective for end-users. They prefer to have a book with data, methods and maps instead to consult disperse papers in national or international journals.

## **Section 8. Publications**

Begueria, S. (in press): Influence of the truncation value in exceedance series modelling of hydrologic extremes. *Journal of Hydrology*.

Garcia-Ruiz, J.M., Marti-Bono, C., Lorente, A. & Begueria, S. (in press): Geomorphological consequences of frequent and infrequent pluviometric and hydrological events in a Mediterranean mountain area. *Mitigation and Adaptation Strategies for Global Change*.

Begueria, S. (2002): Revision de metodos paramétricos para la estimación de la probabilidad de ocurrencia de eventos extremos en Climatología e Hidrología. El uso de series de excedencias y su comparación con las series de máximos anuales. In *La información climática como herramienta de gestión ambiental* (J.M.

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