Empirical estimates of precipitation conditions for landslide triggering in France and Norway

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EGU, Vienna

5 April 2011

Description of SafeLand Work Package (WP1.3)

- Evaluate statistical and empirical models for:
  - predicting critical meteorological elements
  - their thresholds for landslide triggering
- Local and regional scale
- Parts:
  - Models (AMRA, CNRS, EPFL, ICG/NGI)
  - Case studies (Italy, France, Switzerland and Norway)
  - Evaluation of models
- This presentation shows part of WP1.3

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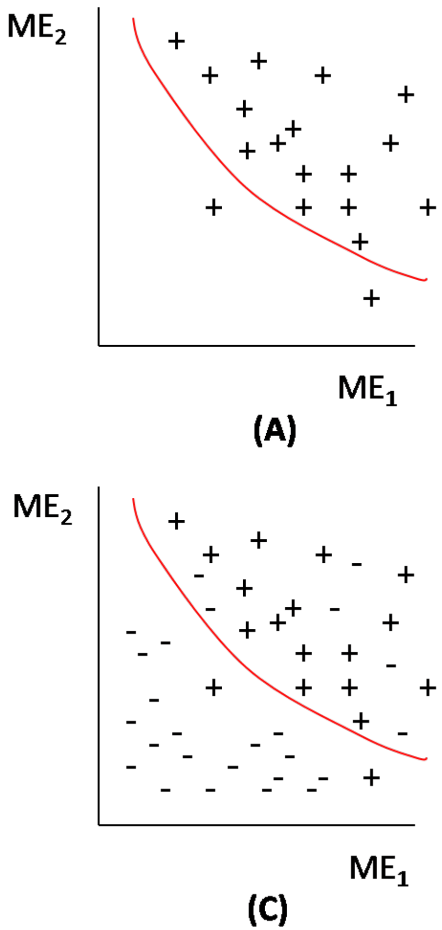
Types of landslides analysed

Type of movement → Material ↓	Fall	Topple	Slide	Spread	Flow
• Rock	Rock fall		Rock slide		Rock flow (*rock avalanche*)
• Soil			Soil slide		
Earth			Earth slide		
Debris					Debris flow

Types of thresholds



ME_1: Meteorological Element 1

ME_2: Meteorological Element 2

+: Meteorological event with observed landslides (LI = ”landslides”)

-: Meteorological event with no observed landslides (LI = ”no landslides”)

—— : Threshold

Cepeda & Devoli (2008)

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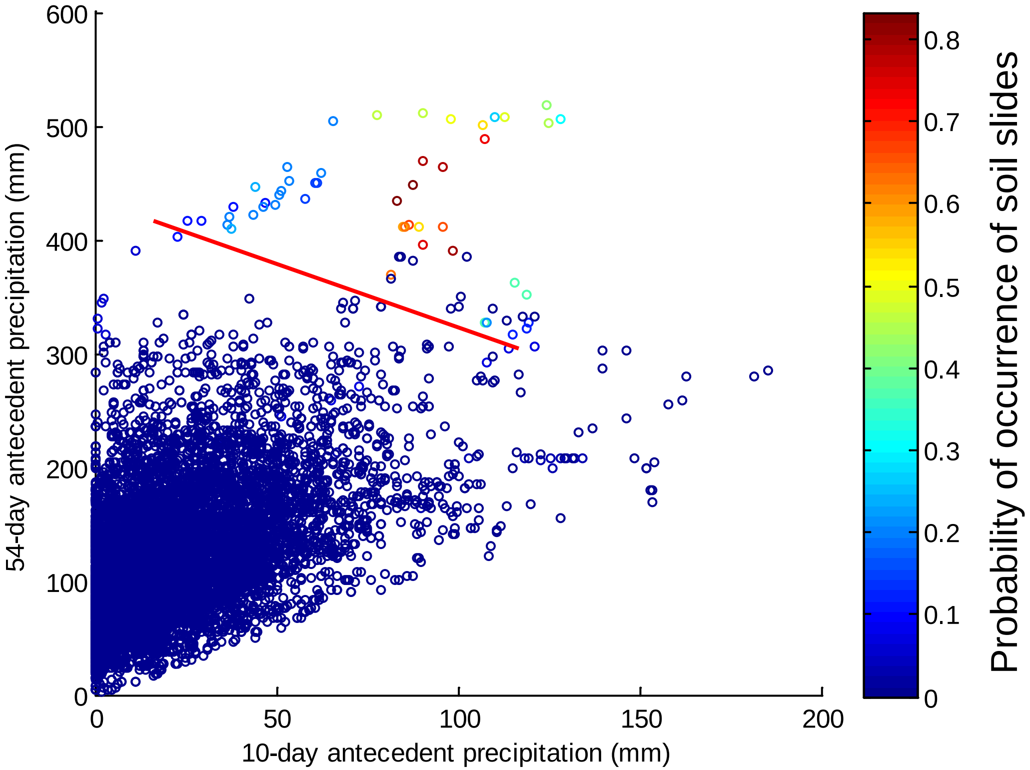
Threshold model (type-C): Antecedent precipitation model

$A_n = \alpha_n$

$A_n = \alpha_n$ and $A_p = \alpha_p$

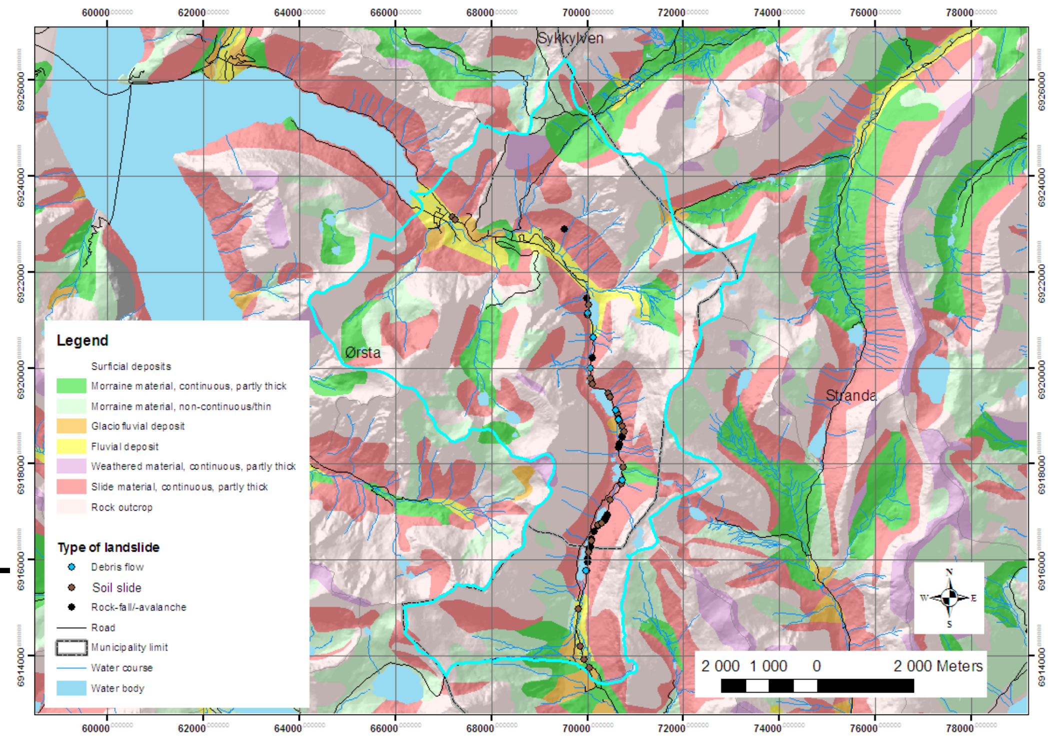
$1 + \alpha_1 A_n + \alpha_2 A_p = 0$



- A_n and A_p: antecedent *n*-day and *p*-day precipitation
- $\alpha_n, \alpha_p, \alpha_1, \alpha_2$: constants of the model

Case 1. Norangselva catchment (Western Norway)

- 56 km^2
- 90 landslides (1892-2005):
  - Debris flows: 13
  - Soil slides: 54
  - Rock-falls, -slides and –avalanches: 23



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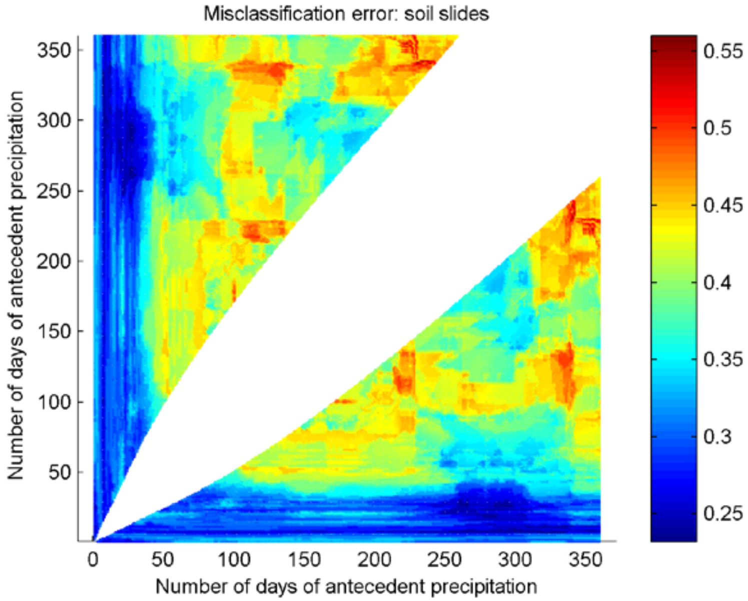
Threshold model: $A_n = \alpha_n$

- *n* was varied from 1 to 360 days
- Optimum *n* minimised false alarms and missed events

Type of landslide	Number of days of antecedent precipitation	Threshold (mm)	Days with landslides		Days without landslides	
			Predicted	Missed	Predicted	False alarms
Debris flows	1	17	3	0	4564	547
Soil slides	7	54	25	5	3681	1403

Threshold model: $1+\alpha_1 A_n+\alpha_2 A_p = 0$

Soil slides

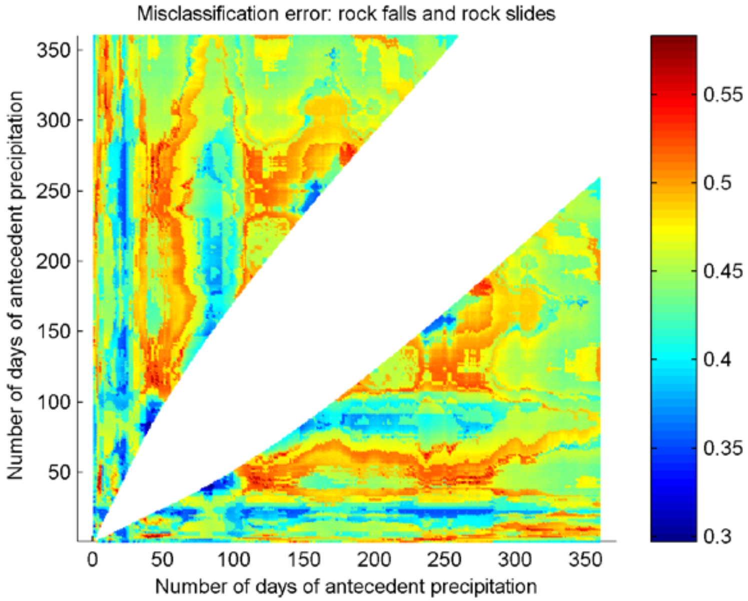


p

n

Lower errors

Rock-falls and -slides



p

n

Higher errors

* Misclassification error: measure of missed events & false alarms

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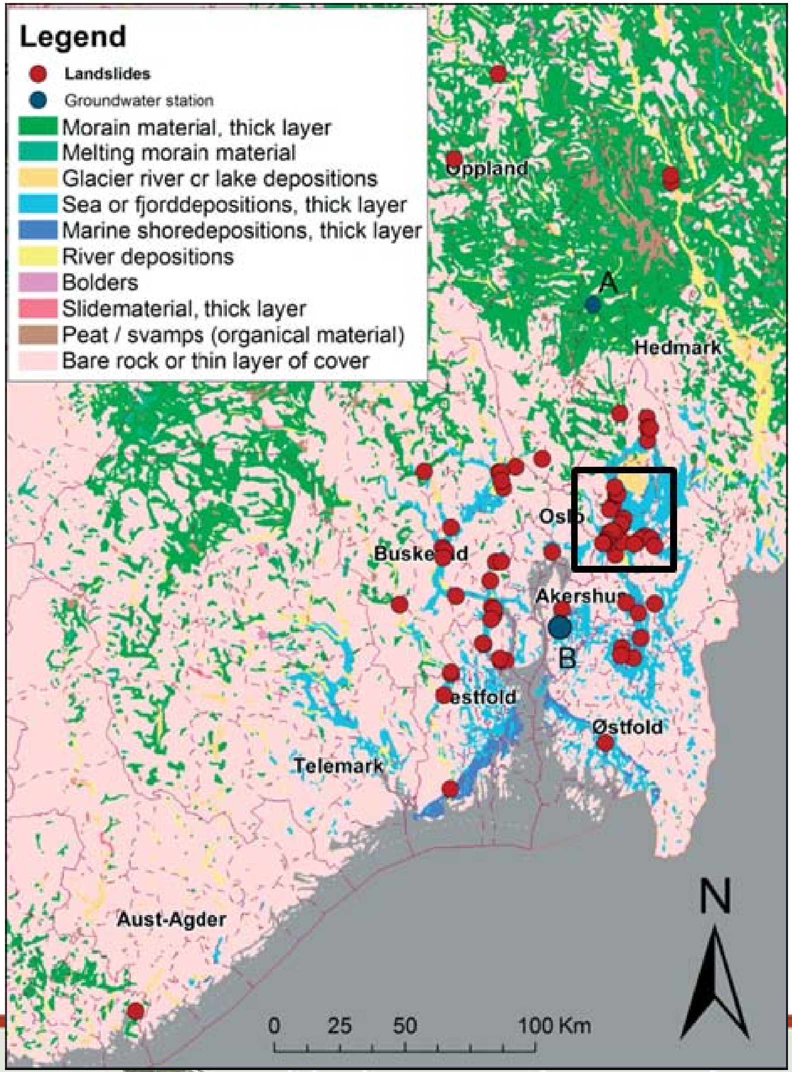
Case 2. Nedre Romerike area

- 30 earth slides in Norwegian landslide database
- River and marine sediments
- All triggered during autumn 2000
- Daily rainfall data 1972-2003



Adapted from Jaedicke & Kleven (2008)

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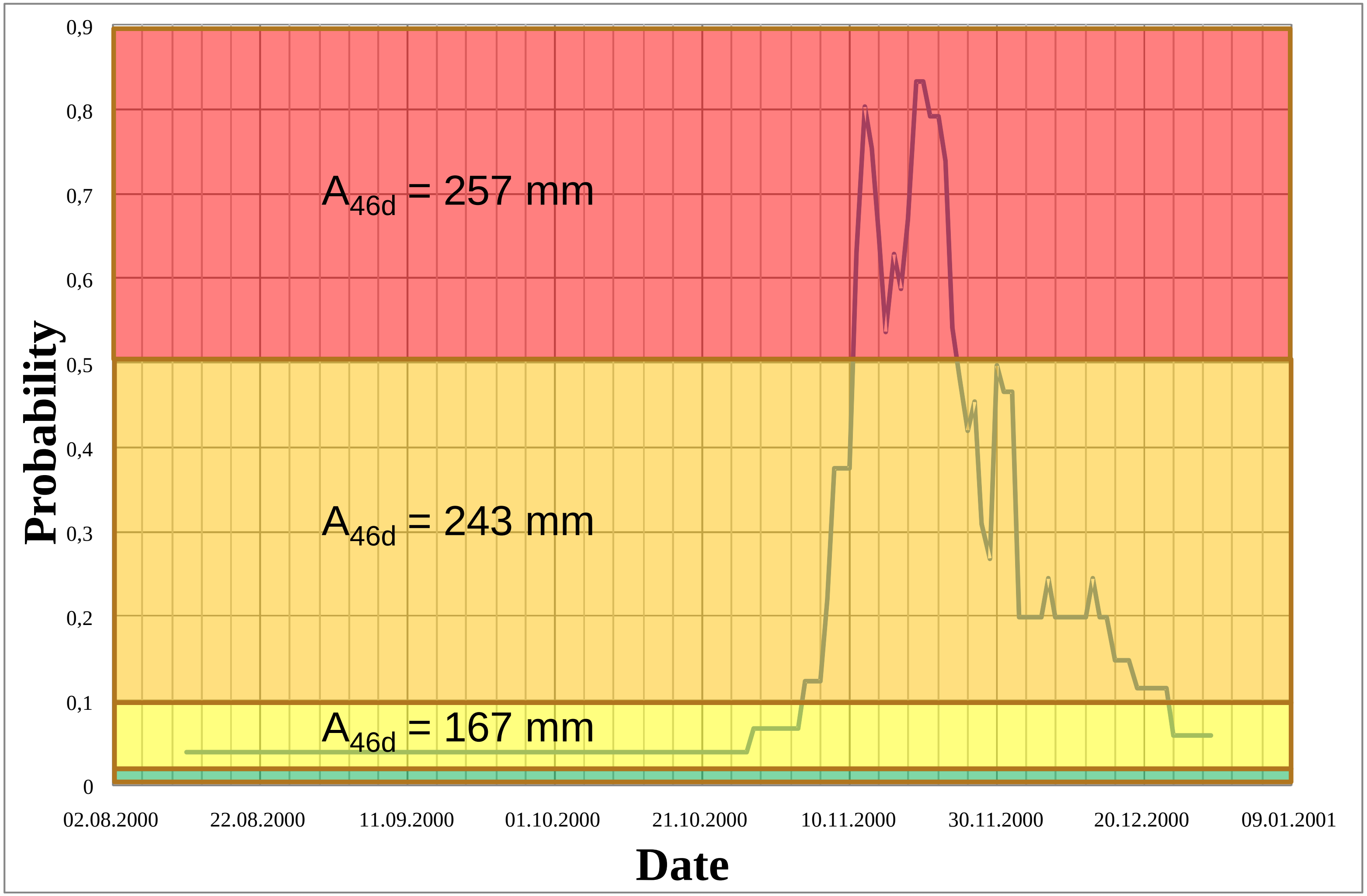
Case 2. Nedre Romerike area

- Problem with dataset: uncertainty in time (or date) of occurrence (from 1 to 64 days)
- Approach in this study: incorporate time uncertainty in the evaluation of the threshold:
  1. For each landslide event, produce a probability density function (PDF) based on the time uncertainty in inventory
  2. Apply addition rule to PDFs of all landslide events
  3. Classify levels of probability of occurrence in time: low, medium, high
  4. Estimate thresholds for each level of probability

Nedre Romerike, Norway



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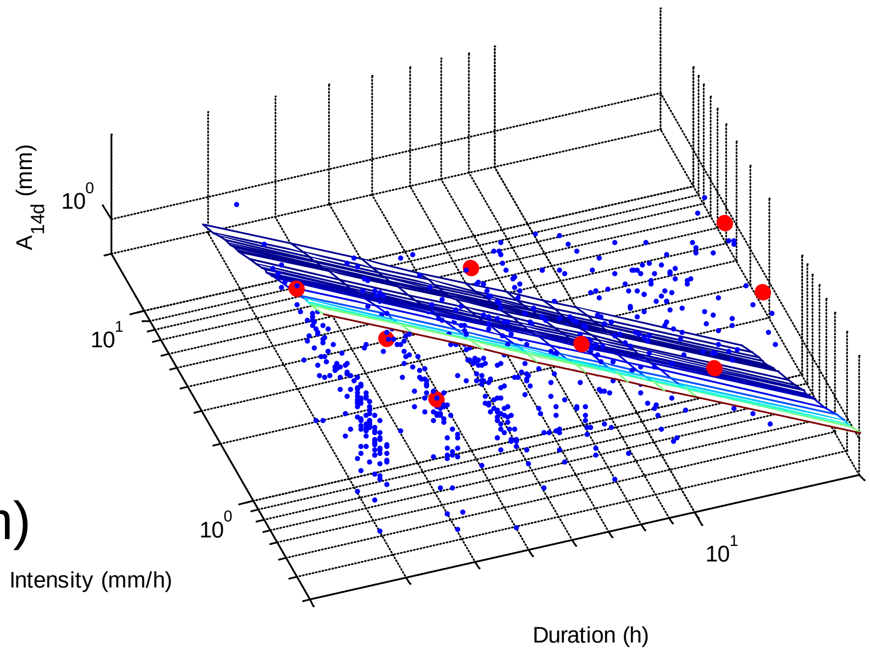
Intensity-Antecedent precipitation-Duration (IAD) model

$$I = [\alpha_1 A_n^{\alpha_2}] D^{\beta}$$

α in *ID* model (the bracketed term $\alpha_1 A_n^{\alpha_2}$)

Where:

- I, D and β as in *ID* model
- A_n: antecedent *n*-day precipitation (mm)
- α_1 and α_2: constants of the model



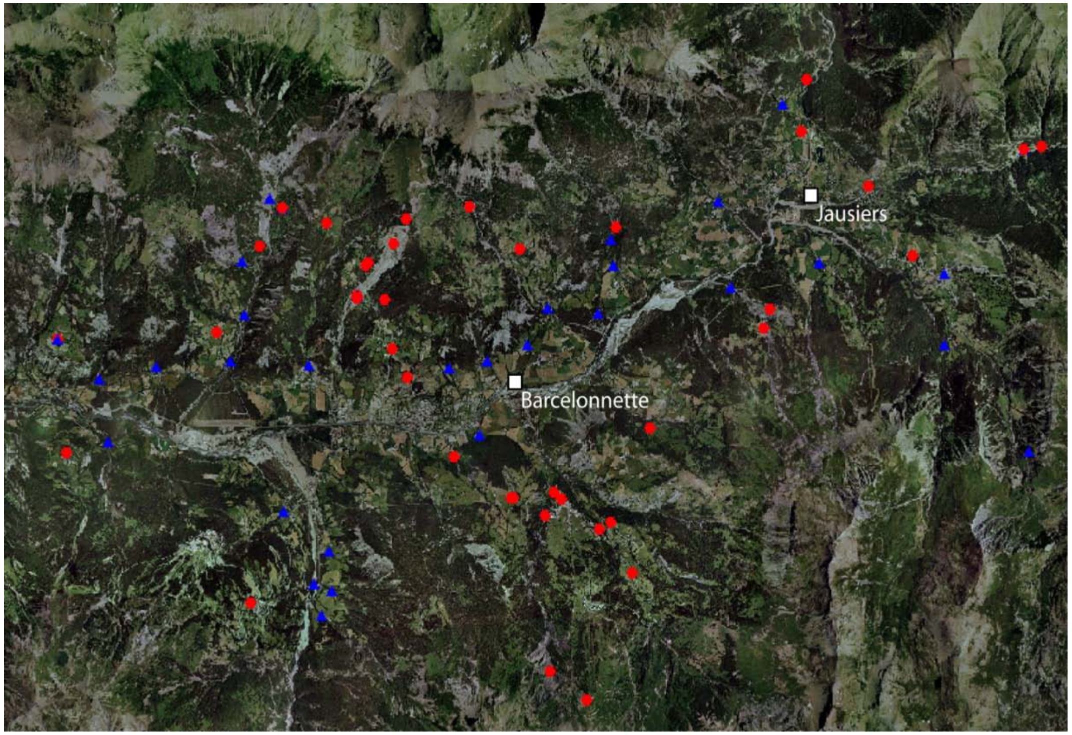
This is a generalisation of the *ID* model.

Cepeda, Nadim, Høeg & Elverhøi (2009)

Barcelonnette (France)

- Type of events:
  - Soil slides
  - Debris flows

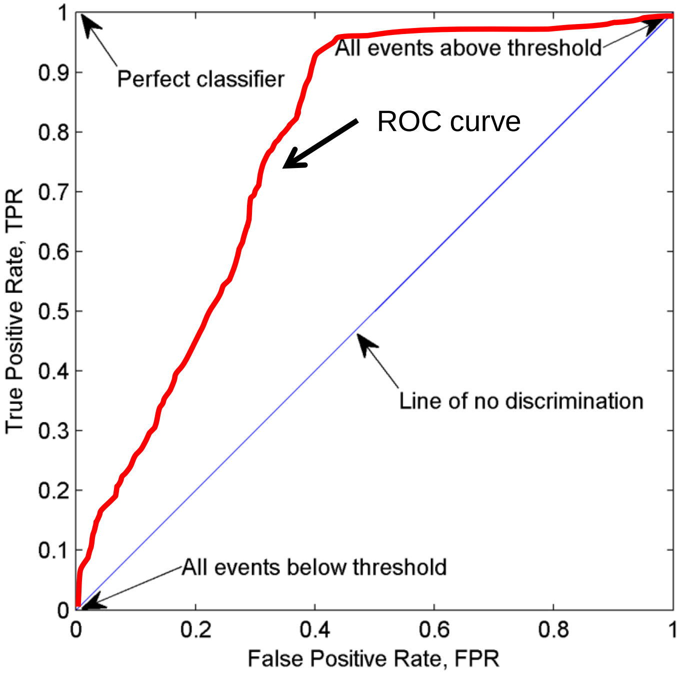
- Precipitation data: hourly



Blue: debris flows
Red: soil slides

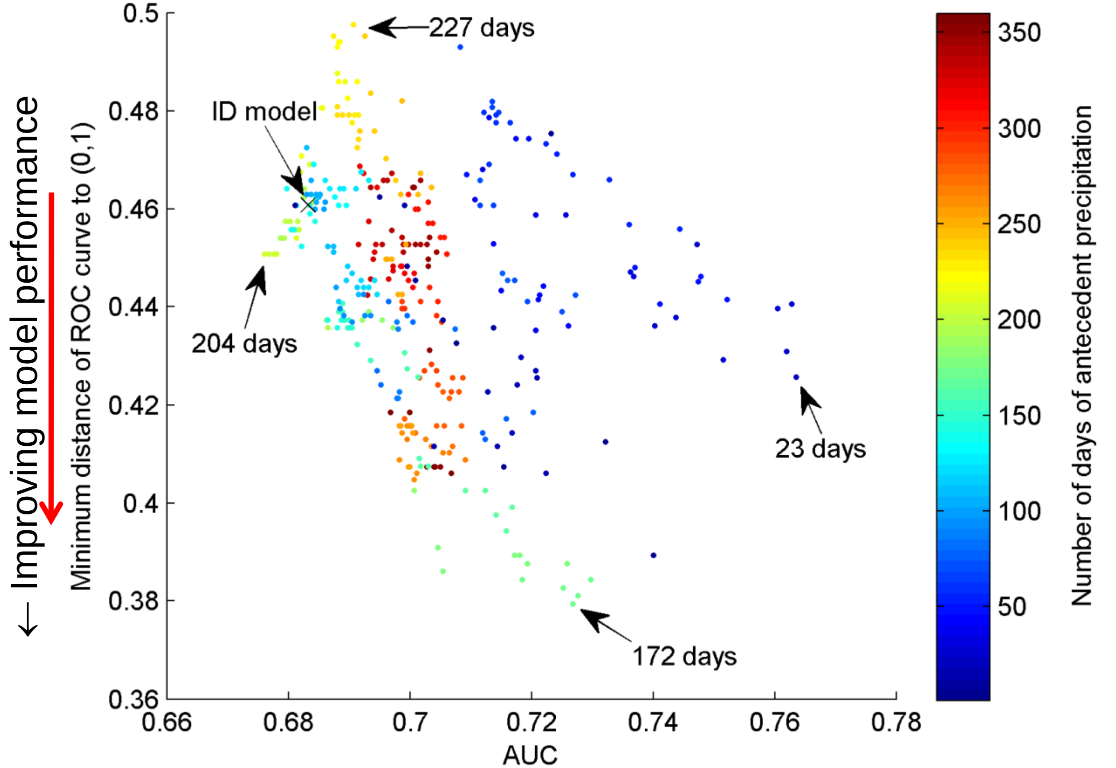
Barcelonnette, France
(*ID* and *IAD* models, soil slides)

ROC space



AUC: area under the ROC curve

Comparison of *ID* and *IAD* models



Improving model performance →

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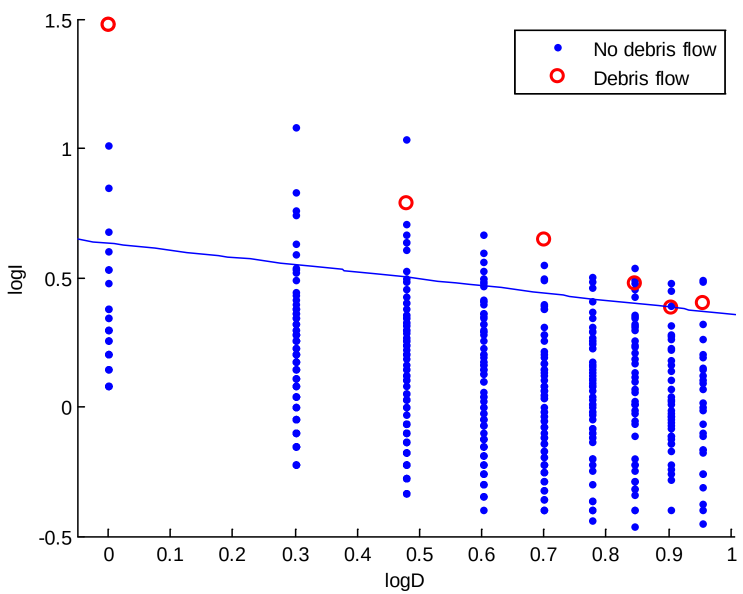
Barcelonnette, France (*ID* and *IAD* models)

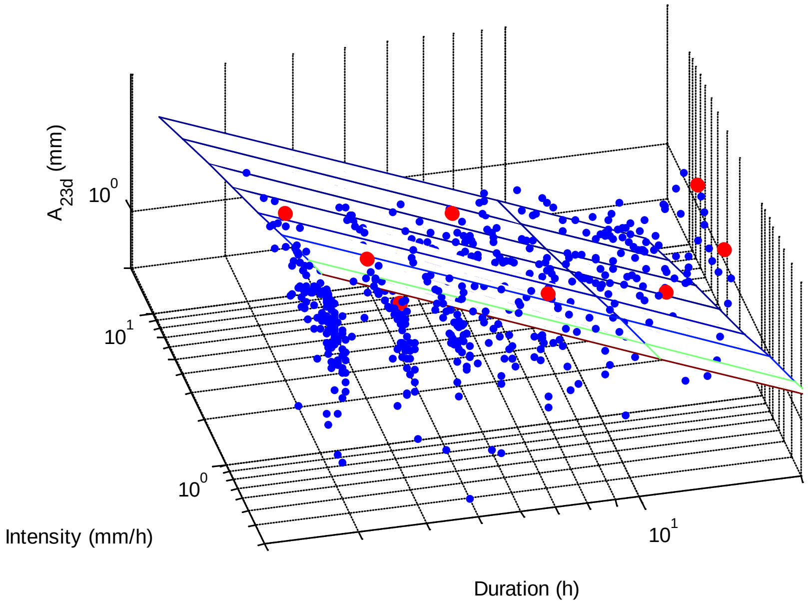
Debris flows



D: 1 to 9 hours

$$I = 4.297 D^{-0.275}$$

Soil Slides



D: 3 to 17 hours

$$I = 181.2 A_{23d}^{-0.6788} D^{-1.5163}$$

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Conclusions

- A simple method was proposed to incorporate uncertainty in time of occurrence in threshold estimation

[Based on the analysed case studies:]

- Triggering rainfall:
  - Soil slides: 3 to 17 hours
  - Debris flows: 1 to 9 hours
- Soil slides well predicted using antecedent precipitation of less than ~50 days
- Rock falls and rock slides poorly predicted. Need to account for other effects (e.g., freeze-thaw)
- Need to include the effect of snow melt

Thank you for your attention

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