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# Nuevos desarrollos del IIAMA-UPV en materia de generación de lluvias y arrastre de vehículos

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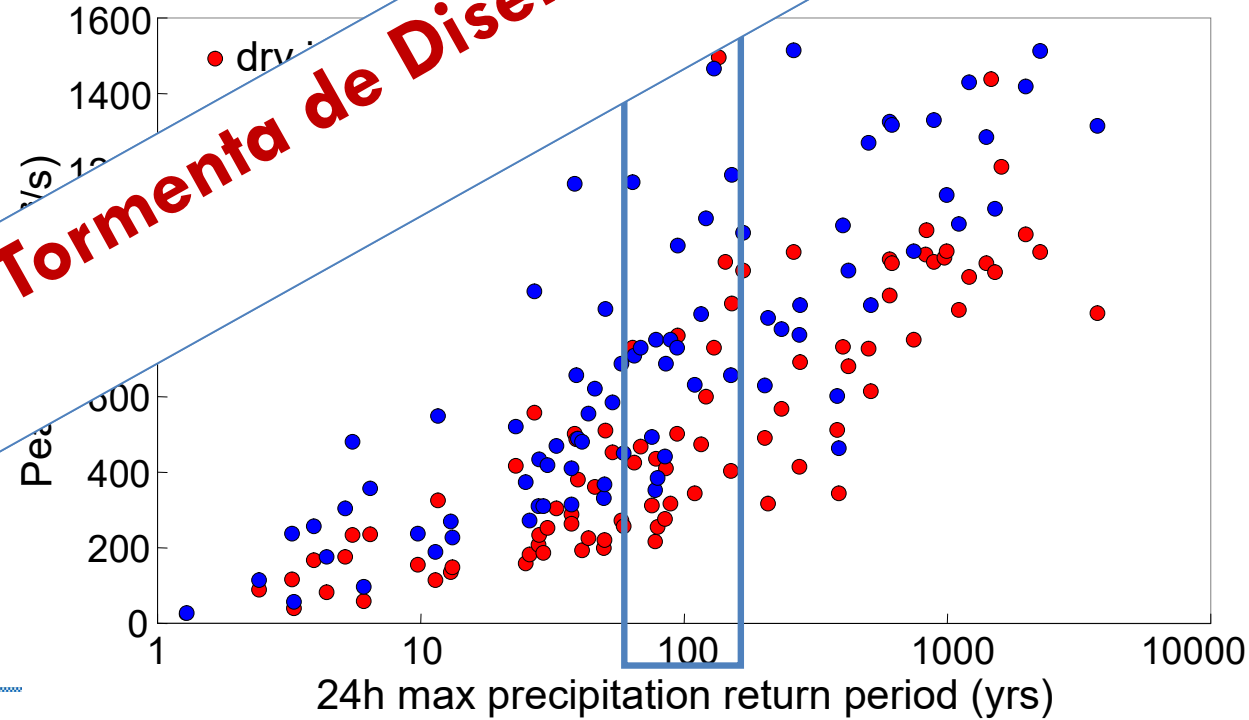
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# Empleo de generadores meteorológicos para la estimación de avenidas extremas incluyendo Cambio Climático

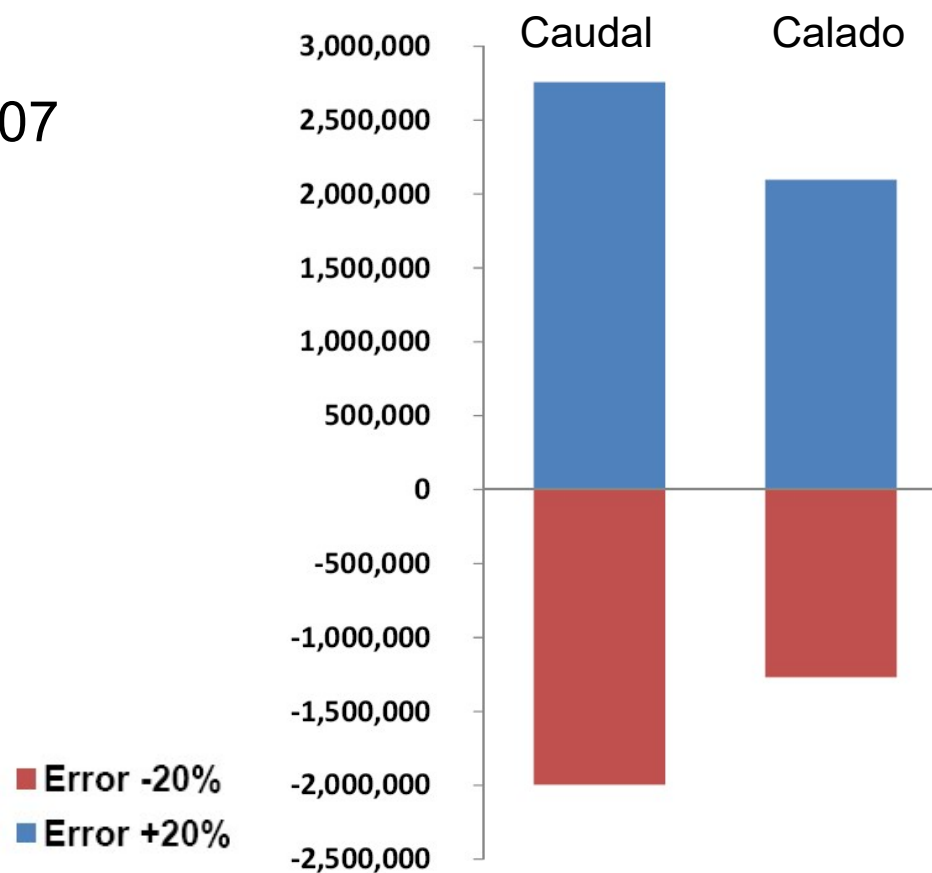
- Caudal pico e hidrograma dependen fuertemente de:
  - Distribución espacio-temporal de la precipitación
  - Humedad del suelo inicial

**¡El paradigma de la "Tormenta de Diseño" es erróneo e incierto!**



Riesgo inundación R. Poyo:  
12,629,016 €/año sólo directos de 2007

**Sensibilidad similar =>**  
**precisión similar en**  
**hidrología e hidráulica**



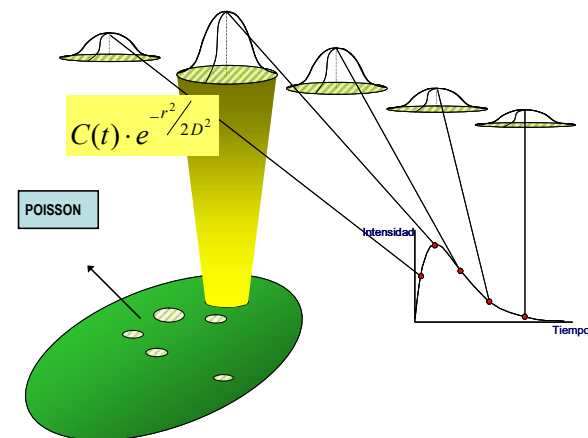
- ❑ Es posible construir un modelo meteorológico continuo o de tormentas => **Generación de tormentas sintéticas (continuo o individuales) → Simulación hidrológica → Simulación hidráulica → Análisis estadístico de h en cada pixel**

- ❑ Pros:

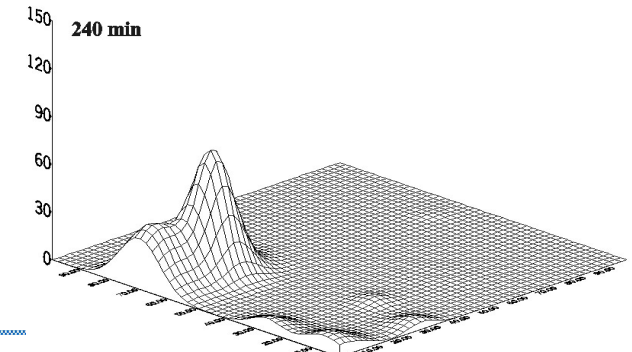
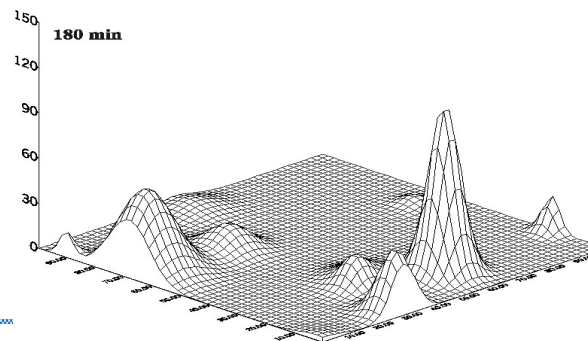
- Inclusión de la variabilidad espacio-temporal
- Tantas tormentas como se quiera

- ❑ Contras:

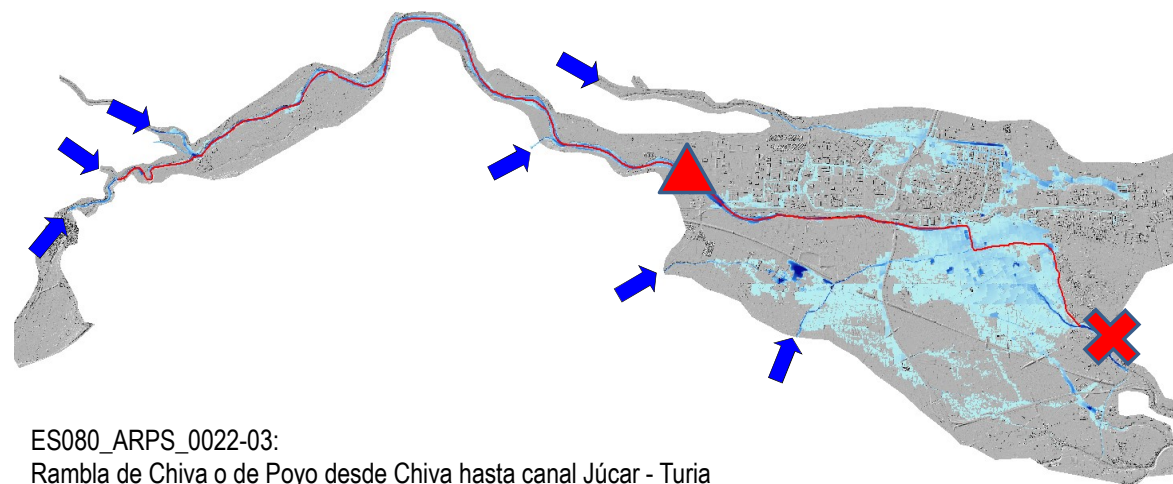
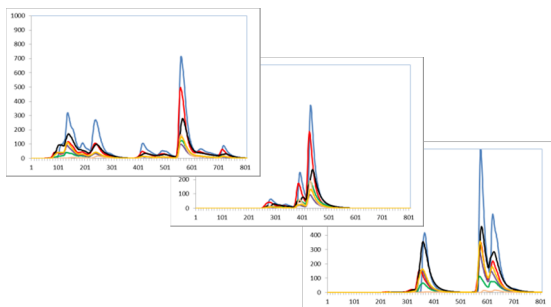
- Adecuación del modelo hidrológico
- Adecuación del modelo meteorológico (especialmente modelos sub-diarios en grandes cuencas)



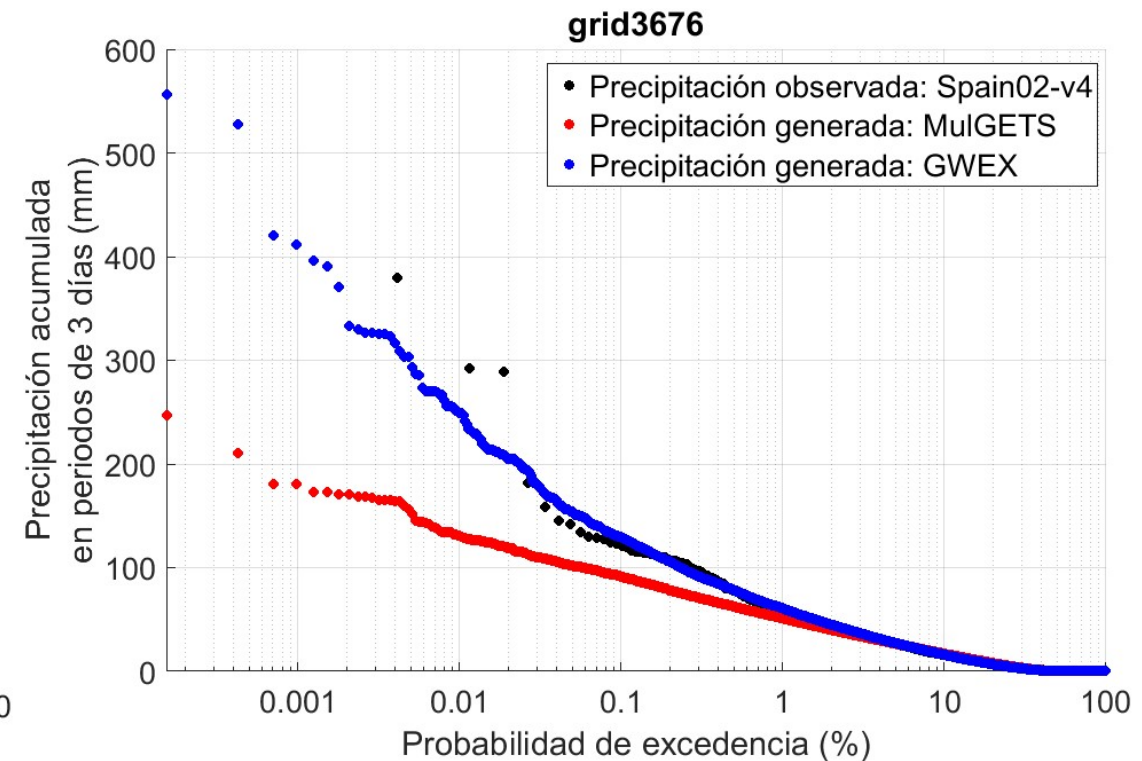
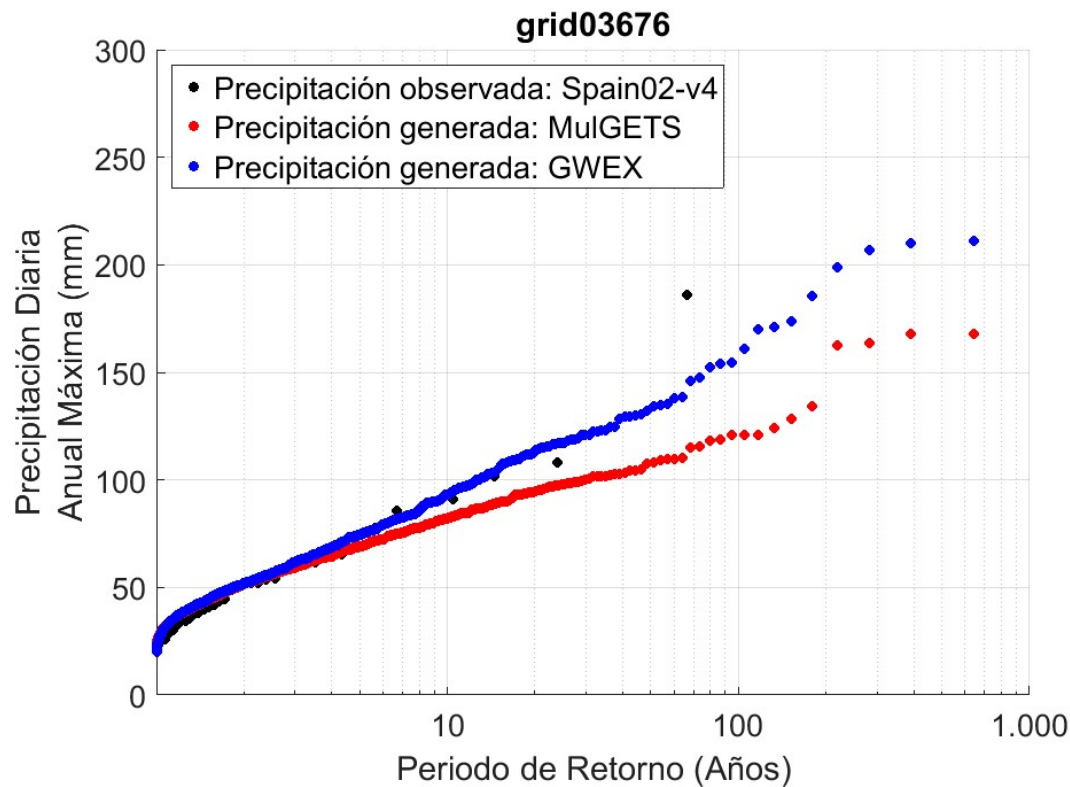
- ❑ Continuous sub-daily, the perfect solution but highly complex and nowadays not for large catchments
  - **ETH model**
- ❑ Sub-daily but for individual events, but problems with initial condition and probabilities (no date)
  - **RAINGEN**
- ❑ Continuous daily, but problems with downscaling
  - **GWEX, MULGETS, ...**



- Zona de inundación ZI (ámbito modelo hidráulico)
- Cuenca vertiente a la ZI (ámbito modelo hidrológico)
- ✗ Punto de interés **PI** (a efectos de asignación probabilidad)
- ▲ Estación de aforo (**EA**) para calibración/validación modelos hidrológicos
- ➔ Puntos de generación de hidrogramas (**PGs**)

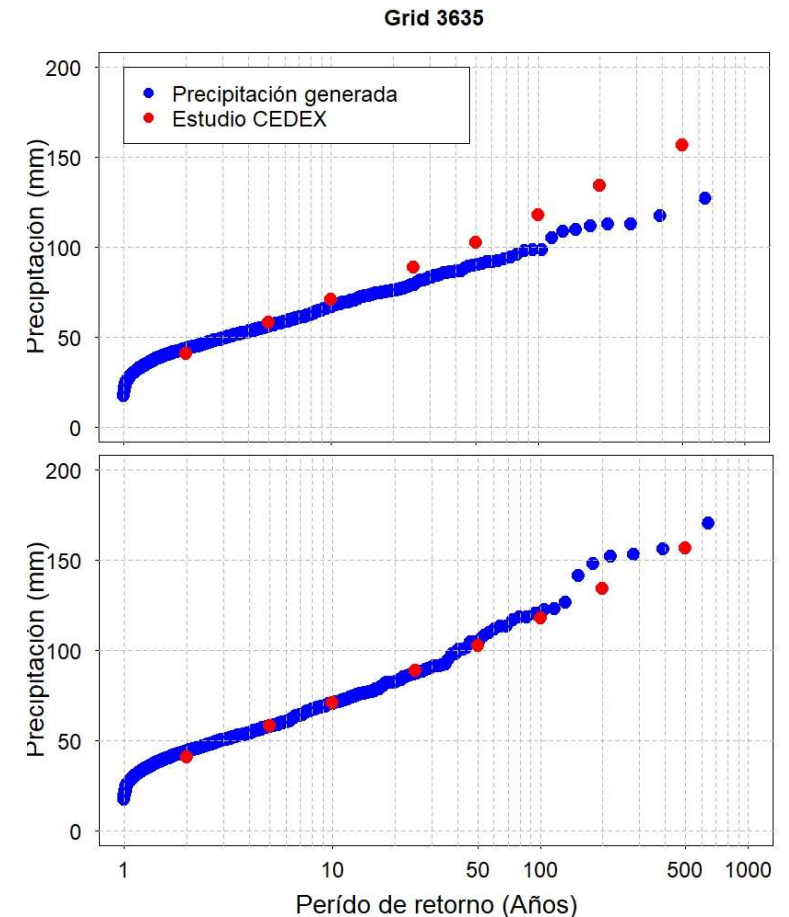


## □ MulGETS (Chen et al., 2014) vs GWEX (Evin et al., 2018)



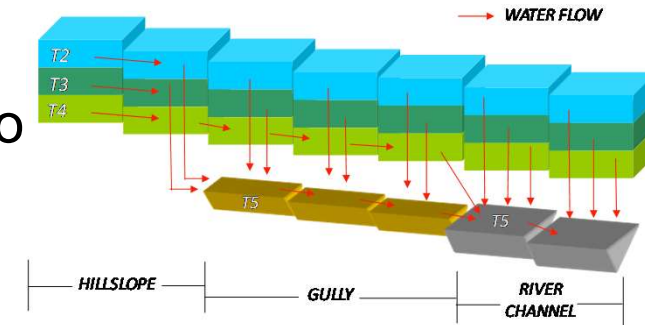


- Primera calibración => datos de precipitación observada de Spain02-v4: 37 años
  - Validación con estudio regional de precipitaciones diarias máximas (*CEDEX*, 1994)
  
- Segunda calibración => Ajuste del parámetro de forma  $\xi$ :
  - Dos poblaciones:
    - Meses de otoño (SON) => A calibrar (prueba y error)
    - Resto de meses



## ❑ Distribuido en el espacio:

- Reproduce la variabilidad espacial del ciclo hidrológico
- Utiliza toda la información espacial disponible
- Ofreciendo resultados en cualquier punto

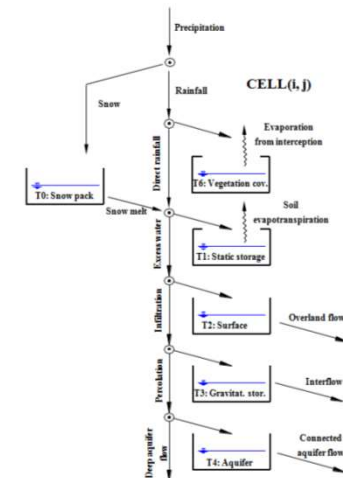


## ❑ Modelo Integral: contabilidad adecuada del estado inicial

- recursos hídricos, inundaciones

## ❑ Facilidad de calibración:

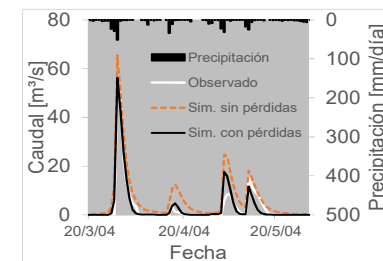
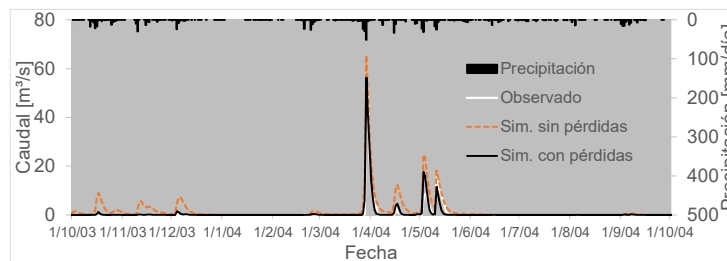
- Parsimonioso
- Posibilidad de calibración automática



□ Calibración (escala diaria):

M<sup>a</sup> Cristina (2003-2004)

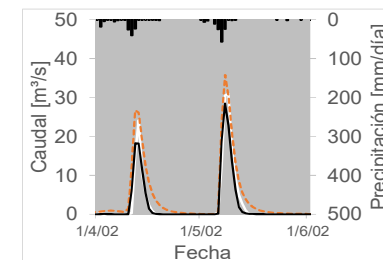
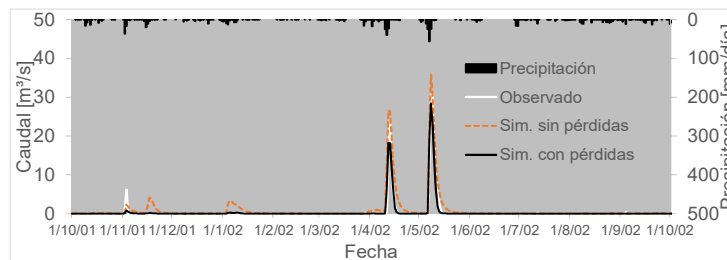
NS = 0.930



□ Validación temporal:

M<sup>a</sup> Cristina (2000-2001)

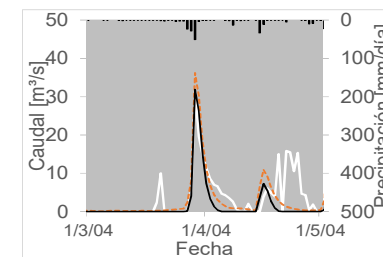
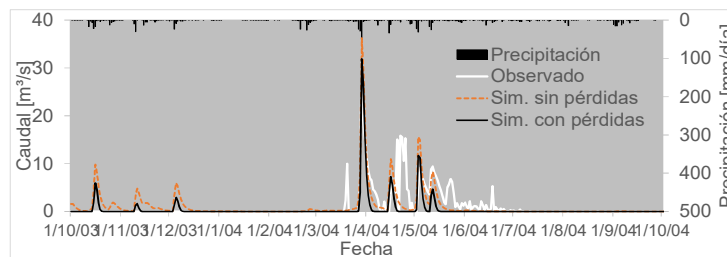
NS = 0.928



□ Validación espacial:

Vall d'Alba (2003-2004)

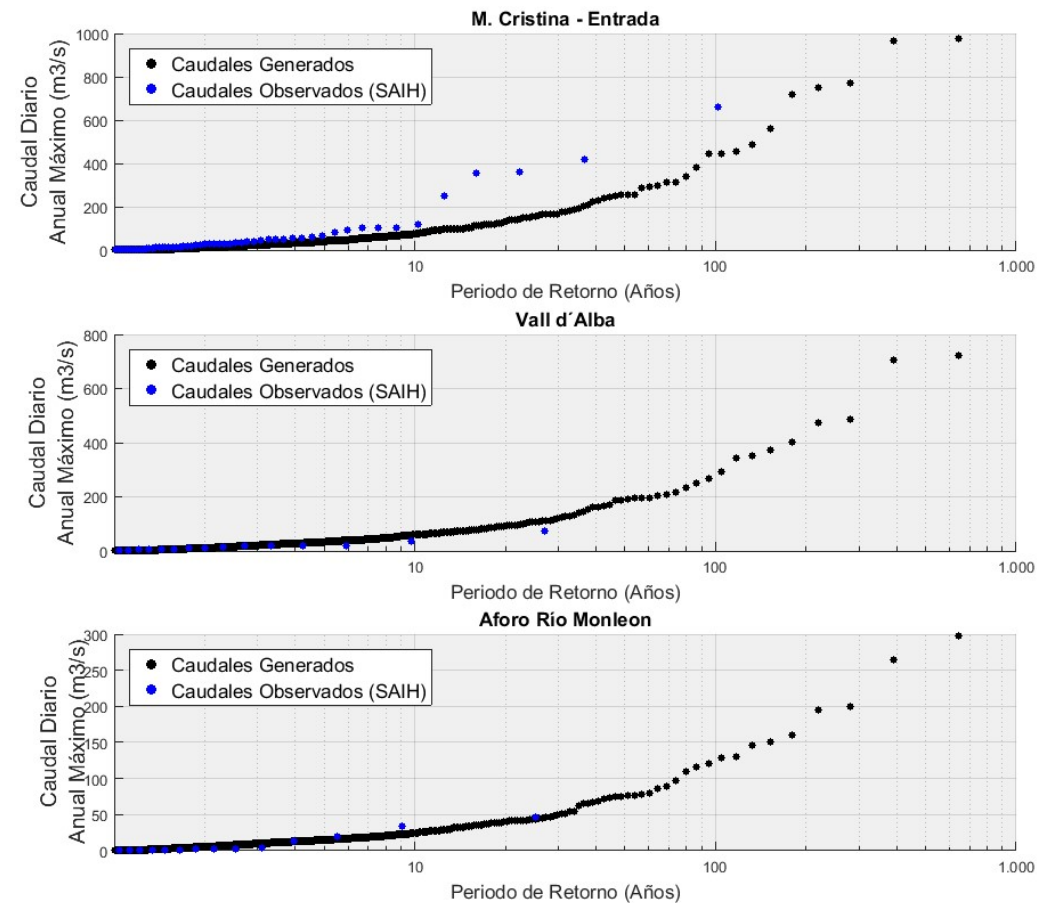
NS = 0.428



(Corrección del desfase temporal y pérdidas)

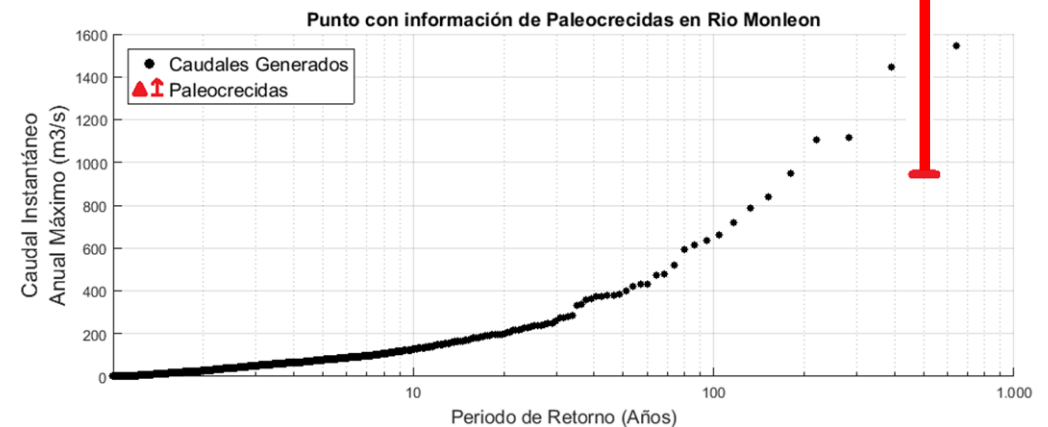
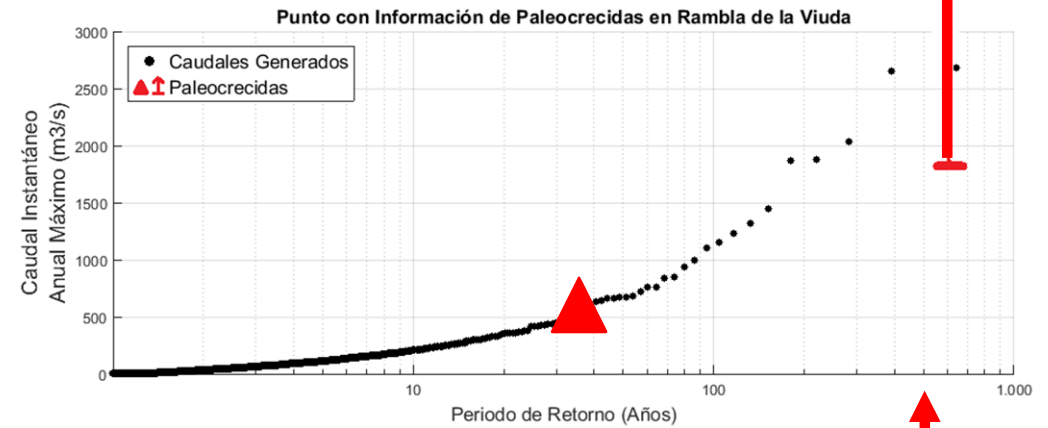
## Validación metodología para caudales bajo T

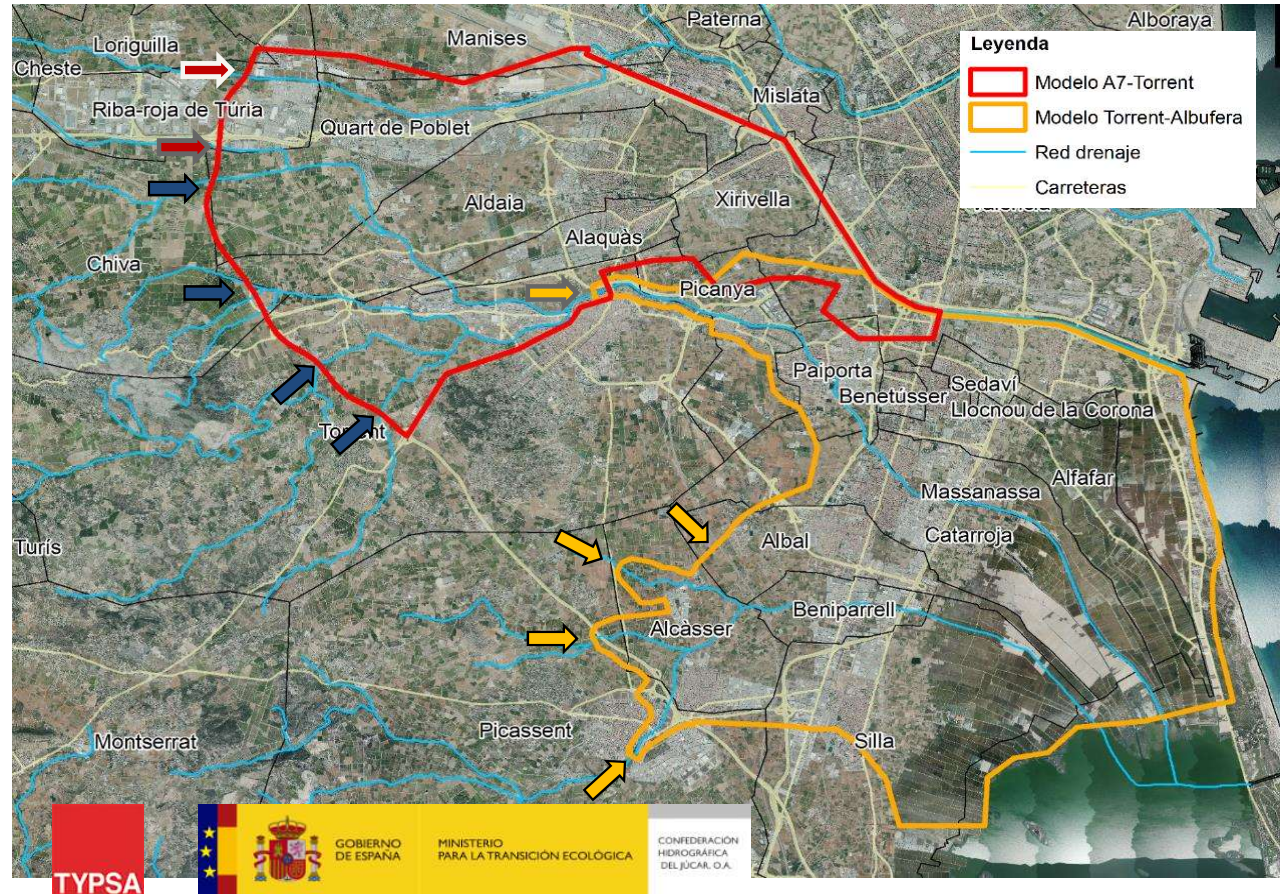
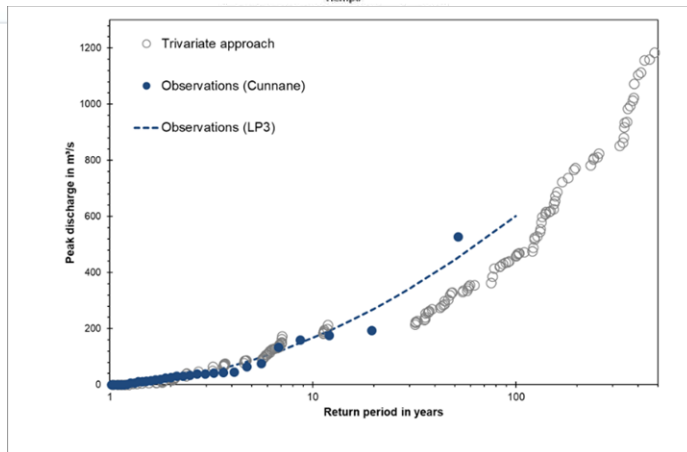
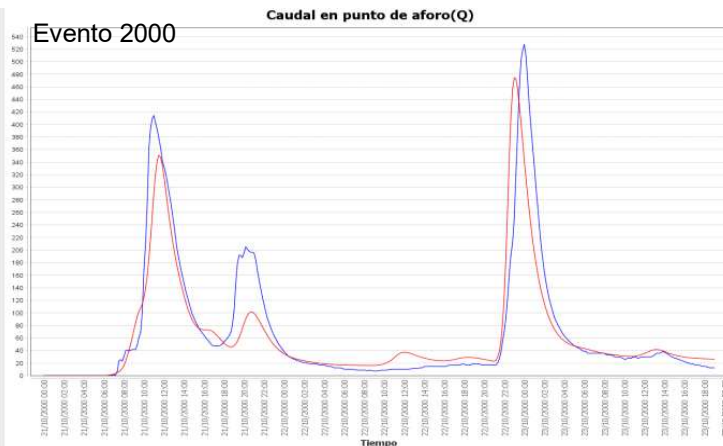
- “Plotting positions” de los caudales observados (SAIH) y los caudales simulados con las lluvias generadas con GWEX en los tres puntos de aforo



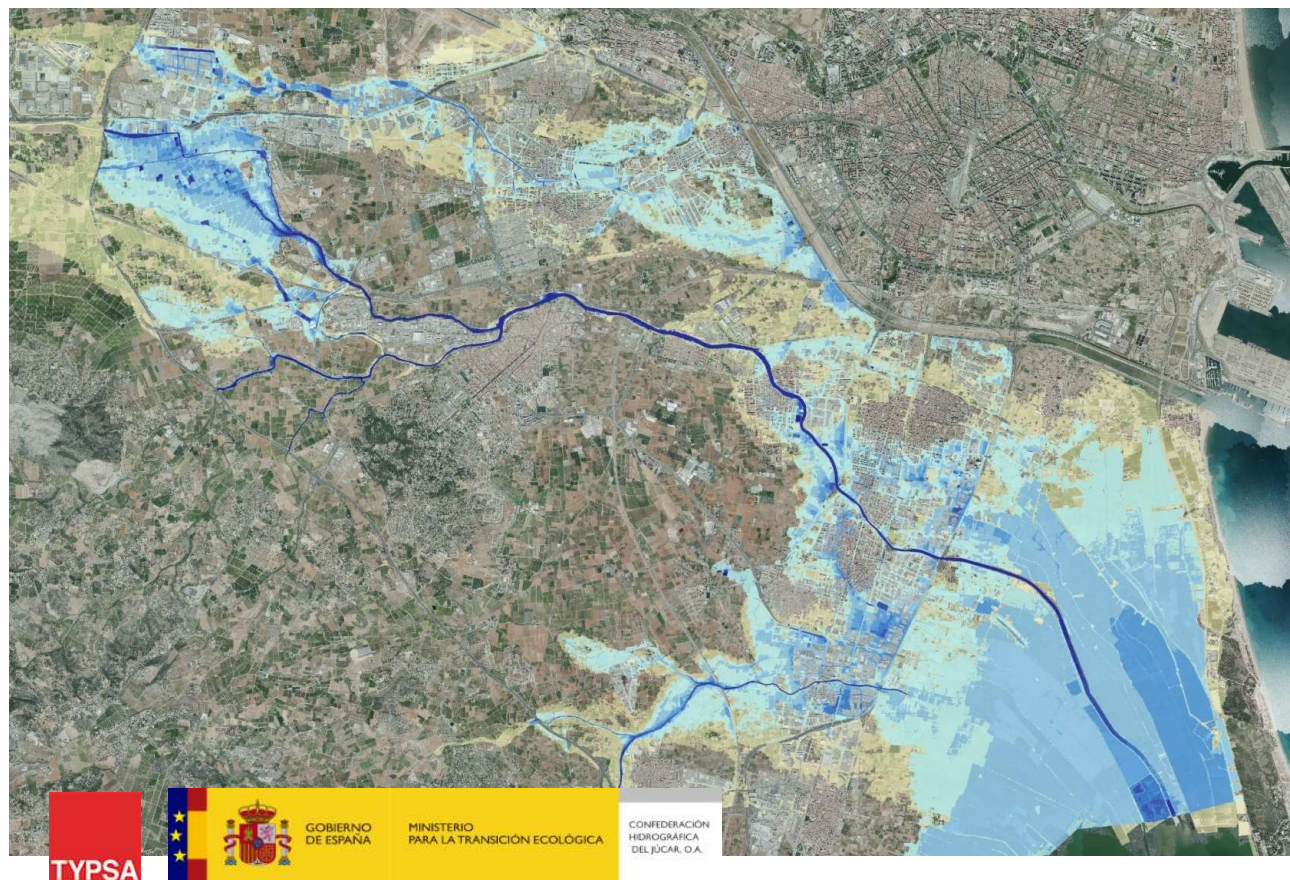
## Validación metodología para caudales **alto T**

- “Plotting positions” de los caudales simulados con las lluvias generadas con GWEX en los puntos con información histórica y de paleocrecidas





| Punto de cálculo      | Caudales 500 años (m³/s) |           |
|-----------------------|--------------------------|-----------|
|                       | Revisión                 | 1er Ciclo |
| Poyo A7               | 1.200                    | 1.407     |
| Saleta                | 190                      | 292       |
| Poyo Torrent          | 1.420                    | 1.412     |
| Picassent-Beniparrell | 450                      | 1.163     |



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CONFEDERACIÓN HIDROGRÁFICA DEL JUCAR, O.A.



UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Jornada de implantación de los PGRI, 14 de noviembre de 2019



GOBIERNO DE ESPAÑA

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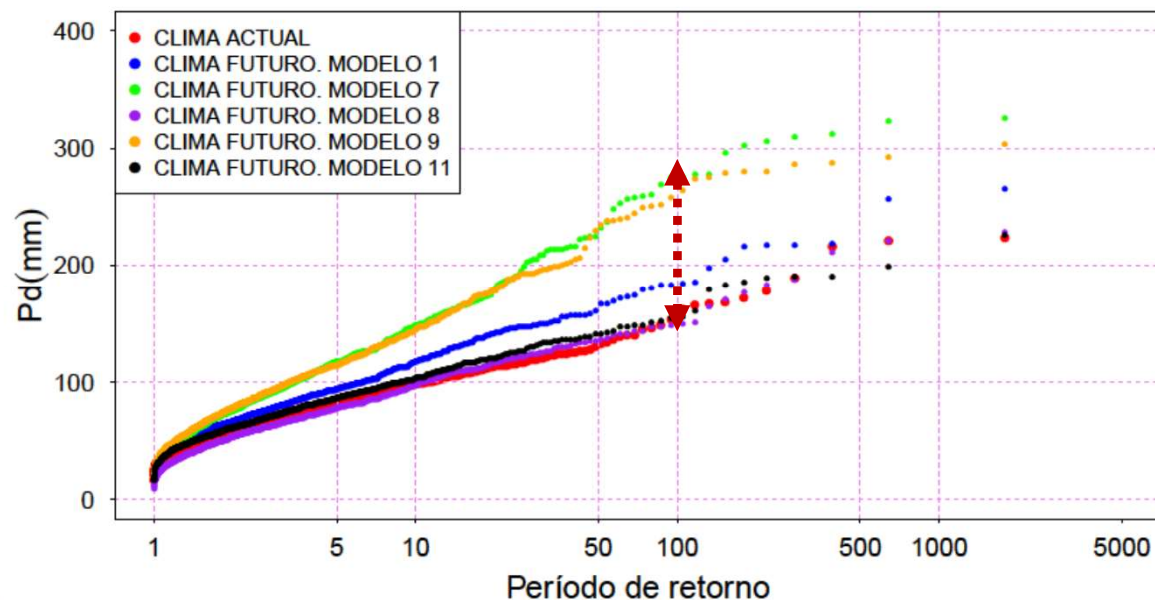
El objetivo es obtener **deltas de inundación** para **T=100** por comparación de la inundabilidad producida con las series de  $T_{\max-\min}$  y  $P_d$  para climas:

❑ **Actual:** Spain02v4 período 1971-2000

❑ **Futuro:** Período **2041-2070** con escenario de emisiones **RCP8.5**

❑ Al menos nos quedamos con CCmax y CCmin

**=> 3 modelos meteorológicos**





# Peligrosidad y riesgo de arrastre de vehículos



□ Desarrollar una metodología para la **adecuada identificación en el espacio del riesgo de arrastre de vehículos:**

- Para Zonas de Inundación
- Simplificaciones y adaptaciones para badenes de cruce de río

⇒ Primero hay que definir un criterio de estabilidad

- ❑ Nowadays, there are a dozen stability criteria with different hypothesis and simplifications
- ❑ After a literature review we selected the criterion ...



Journal of  
Flood Risk  
Management

CIWEM

REVIEW AND ANALYSIS OF VEHICLE STABILITY MODELS  
DURING FLOODS AND PROPOSAL FOR FUTURE  
IMPROVEMENTS

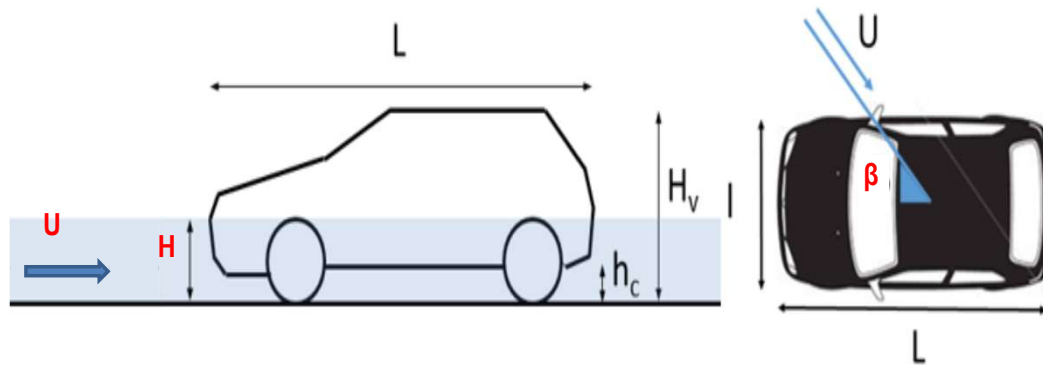
by:  
**Ricardo A. Bocanegra, Félix Francés  
and Francisco J. Vallés**

**Published in 2019**

## Mobility Parameter $\theta_V$

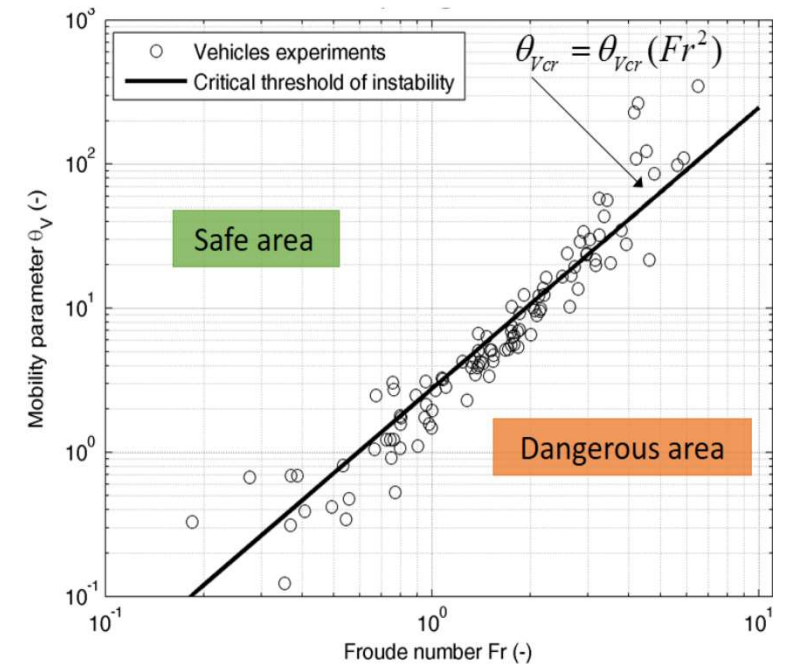
Based on flood ( $H$ ), **vehicle characteristics** and the angle of flow incidence  $\beta$

$$\theta_V = \frac{2L}{(H_v - h_c)} * \frac{l}{l * \cos\beta + L * \sin\beta} * \left( \frac{\rho_c * (H_v - h_c)}{\rho * (H - h_c)} - 1 \right)$$



## Critical Threshold $\theta_{Vcr}(H, U)$

$$\theta_{Vcr} = 8.2 * Fr^2 - 14.1 * Fr + 5.4$$

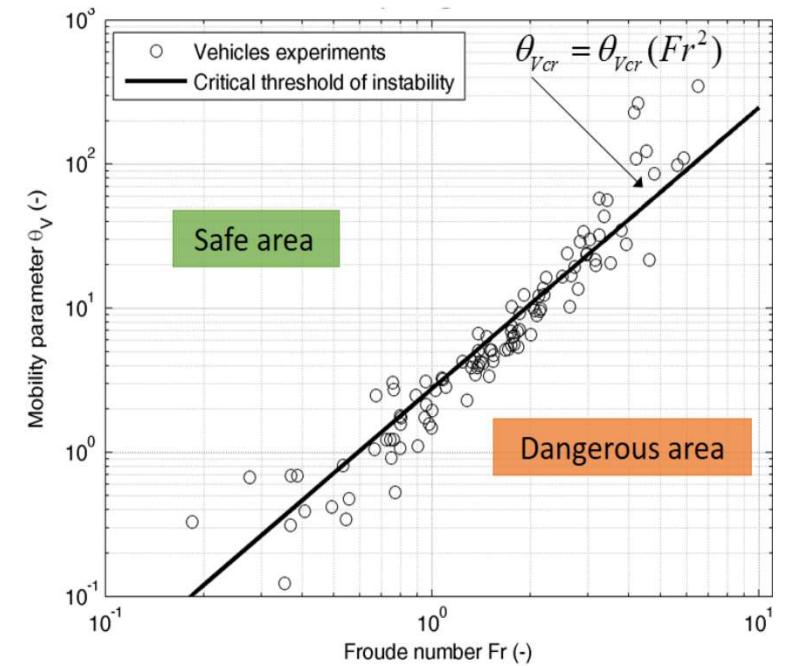
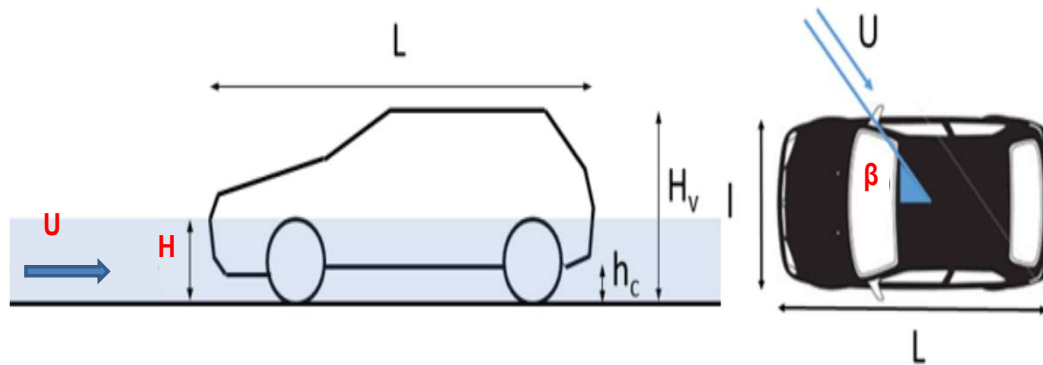


Source: Arrighi et al. (2016)

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## Stability criterion:

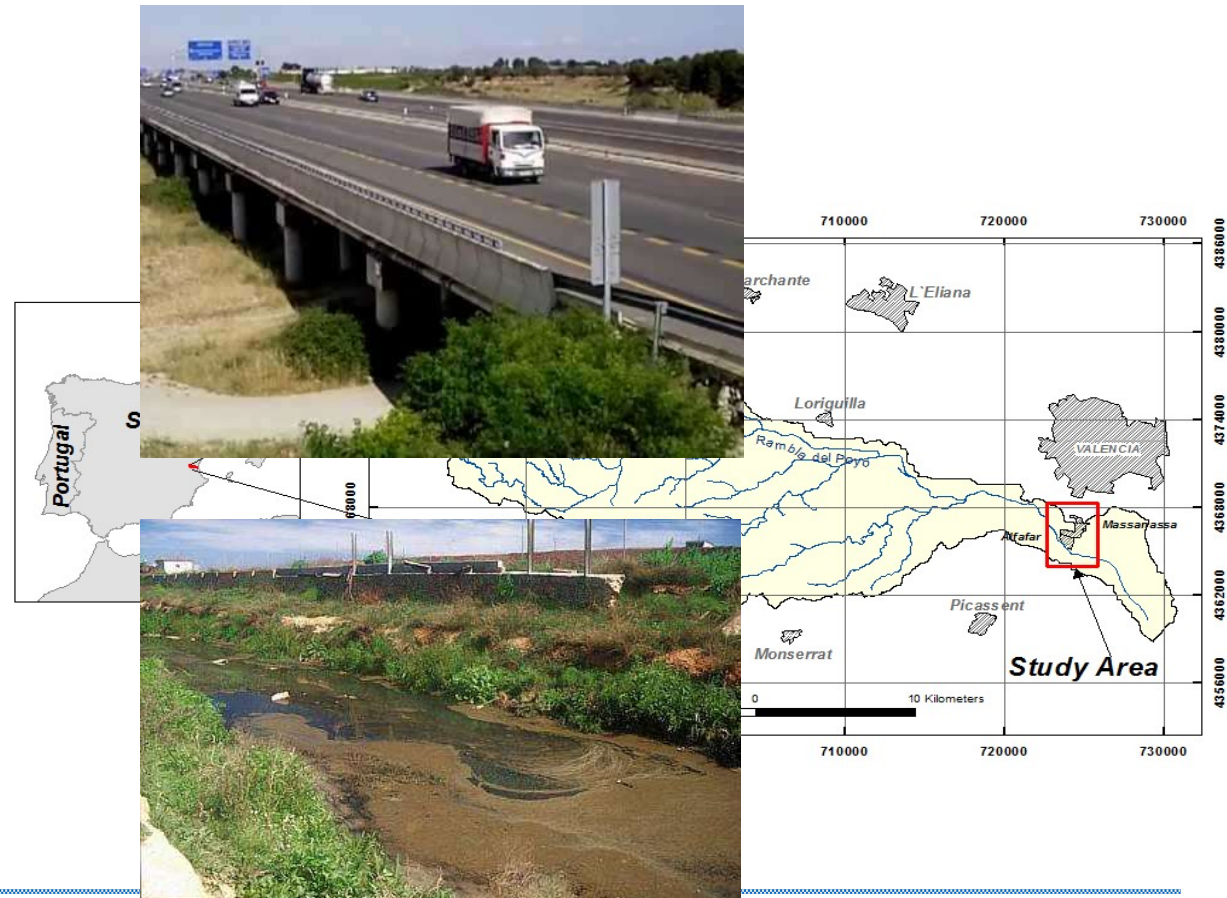
$$S_i = \frac{\theta_{Vcr}}{\theta_V} \begin{cases} > 1 & \text{In motion by sliding} \\ = 1 & \text{Incipient motion by sliding} \\ \in [0, 1[ & \text{Vehicle at rest} \\ < 0 & \text{In motion by floating} \end{cases}$$



Source: Arrighi et al. (2016)

Source: Arrighi et al. (2016)

- Catchment area = 430 Km<sup>2</sup>
- Mediterranean semi-arid climate
- Medicanes in Autumn
- Ephemeral river
- Disappears in floodplain
  
- Case study: municipalities of Massanassa and Alfafar located in the lower part of the catchment
  - Direct risk in 2007: 550,338 €/year
  - 18,205 cars can be affected



| Parameter                    | Vehicle i             |                      |                           |                                 |
|------------------------------|-----------------------|----------------------|---------------------------|---------------------------------|
|                              | Utility<br>Seat Ibiza | Compact<br>Seat León | Small SUV<br>Peugeot 2008 | Medium SUV<br>Volkswagen Tiguan |
| Length (m)                   | 3.683                 | 4.184                | 4.159                     | 4.433                           |
| Width (m)                    | 1.610                 | 1.742                | 1.739                     | 1.809                           |
| Height (m)                   | 1.421                 | 1.439                | 1.556                     | 1.665                           |
| Ground clearance (m)         | 0.124                 | 0.12                 | 0.165                     | 0.175                           |
| Density (Kg/m <sup>3</sup> ) | 108.00                | 125.86               | 104.41                    | 115.26                          |
| <b>Proportion gi</b>         | <b>0.262</b>          | <b>0.322</b>         | <b>0.148</b>              | <b>0.268</b>                    |

Seat Ibiza



Seat León



Peugeot 2008

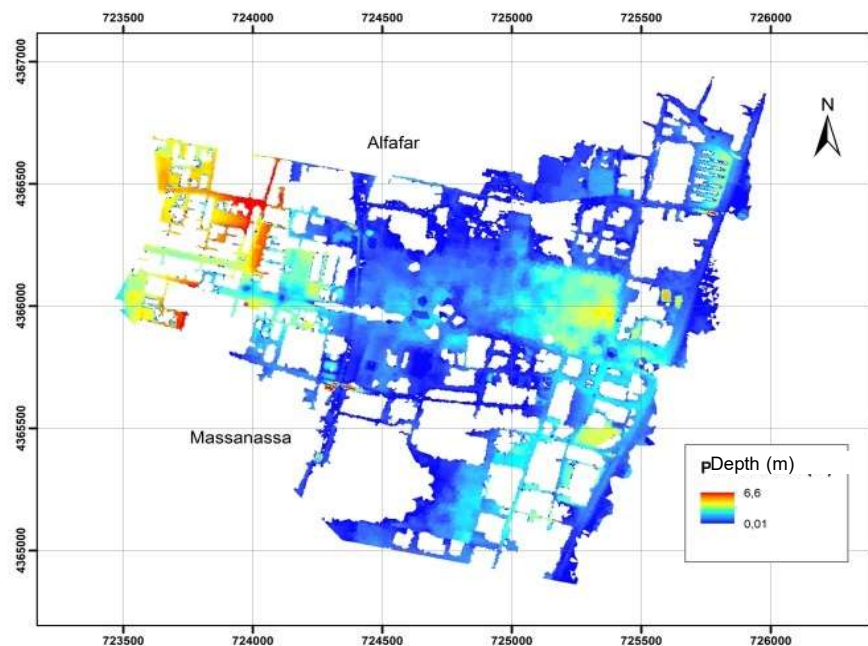


Volkswagen Tiguan

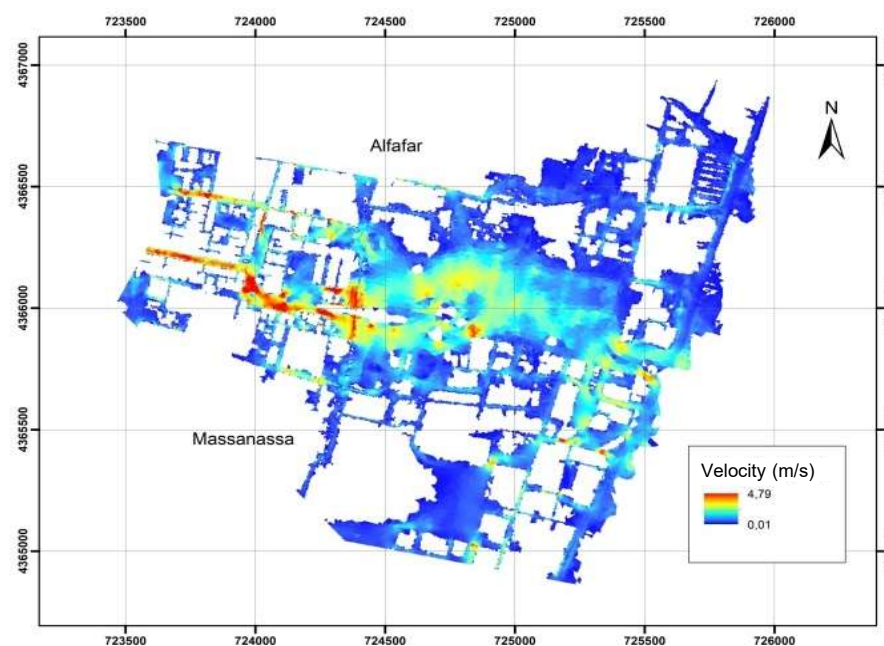


Available for return periods of 10, 25, **50, 100 and 500**

## Flood for Tr 100 years



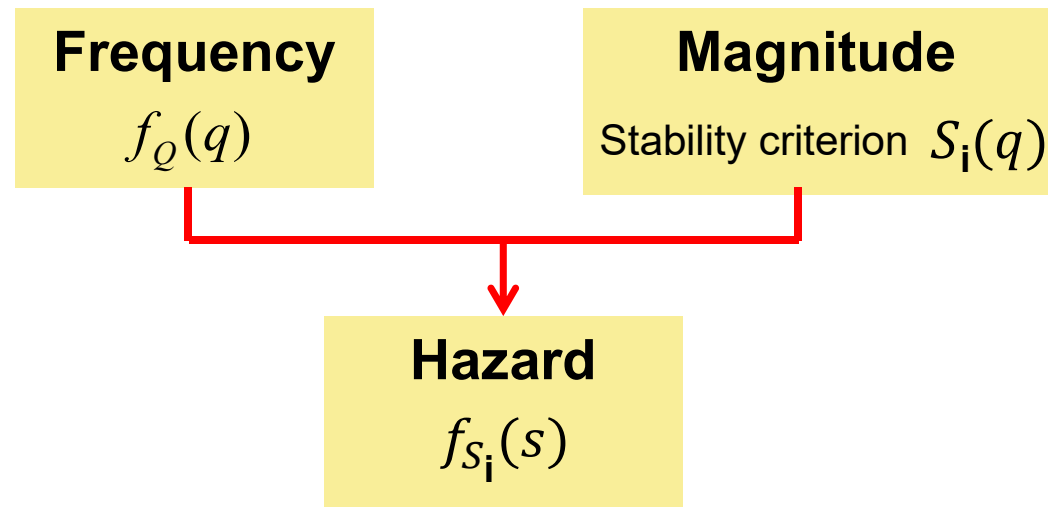
Depths (**H**)



Velocities (**U<sub>h</sub>**)

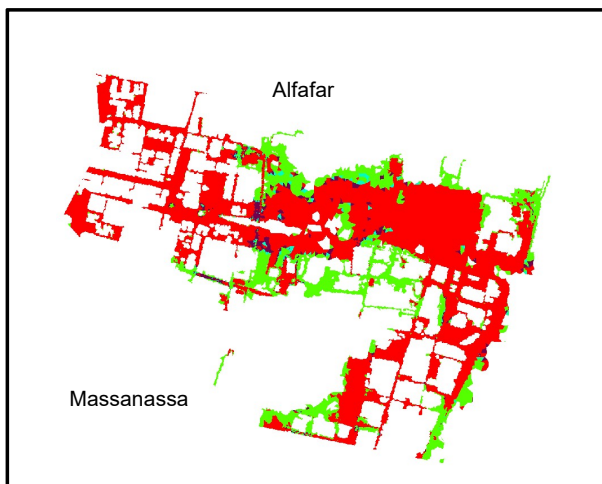


- Vehicle flood hazard can be defined as the **probability** for the conditions that cause the loss of stability of vehicles (**Si**) => depends on type of car i

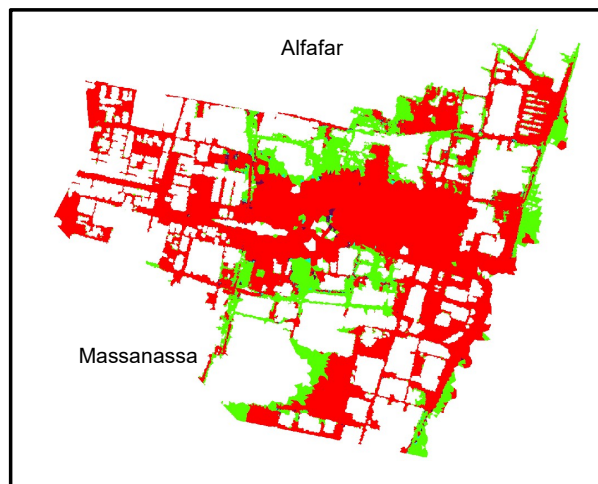


## Utility Car Flood Hazard Hazard Index $S_i(h,u)$

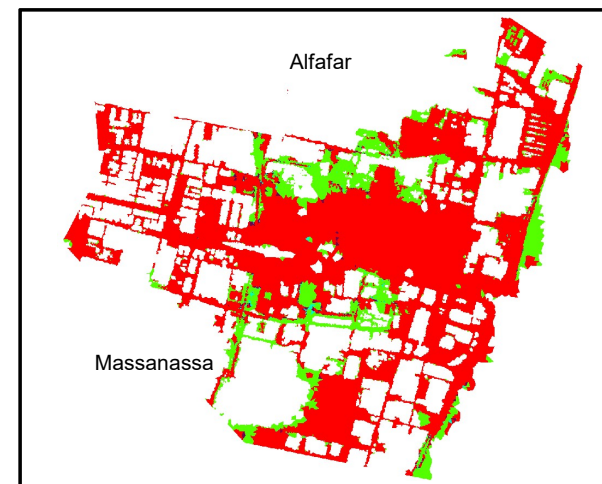
Tr = 50 years



Tr = 100 years

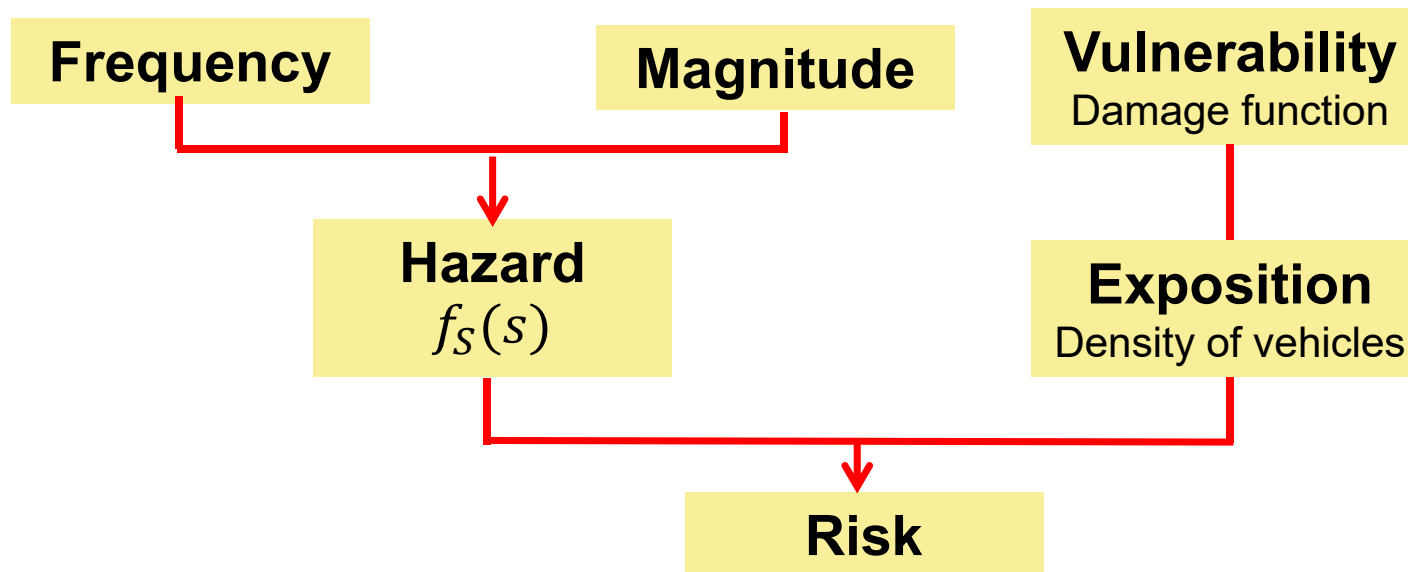


Tr = 500 years



| Loss of stability by flotation | Safety Zones |           | Loss of stability by sliding |       |
|--------------------------------|--------------|-----------|------------------------------|-------|
| < 0                            | 0 – 0.5      | 0.5 – 1.0 | 1.0 – 1.5                    | > 1.5 |
|                                |              |           |                              |       |

- Defined as the combination of the probability of a vehicle being swept away or floated and the **density of vehicles** driving or being parked on floodplain:

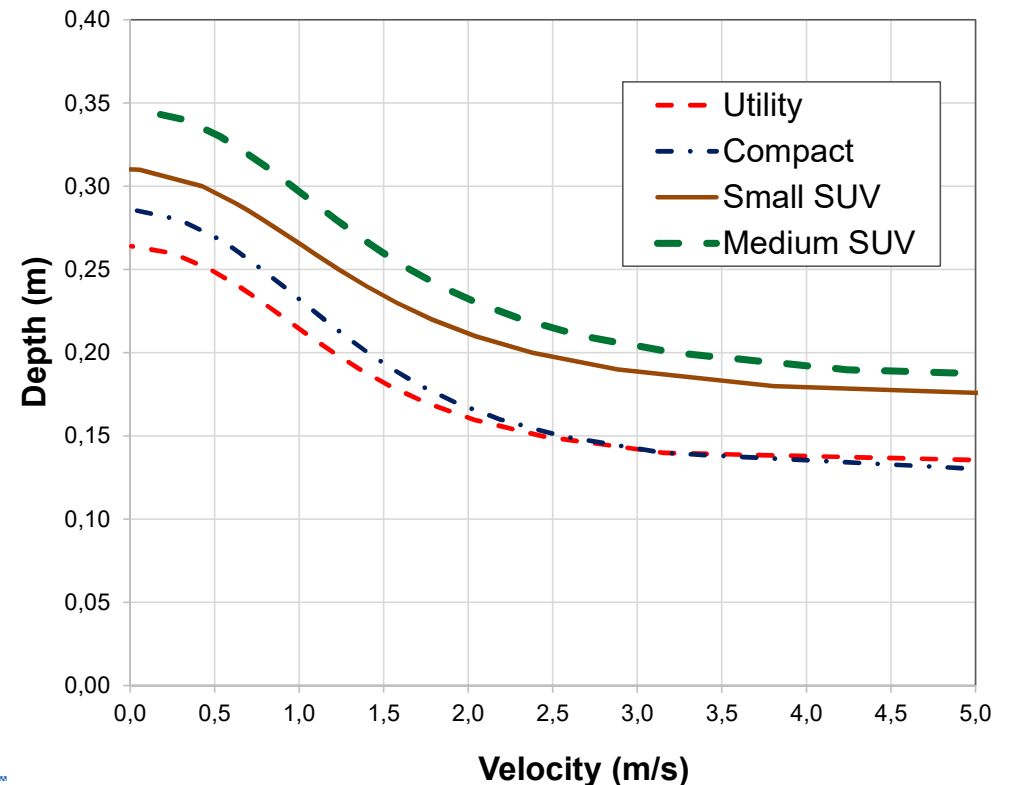


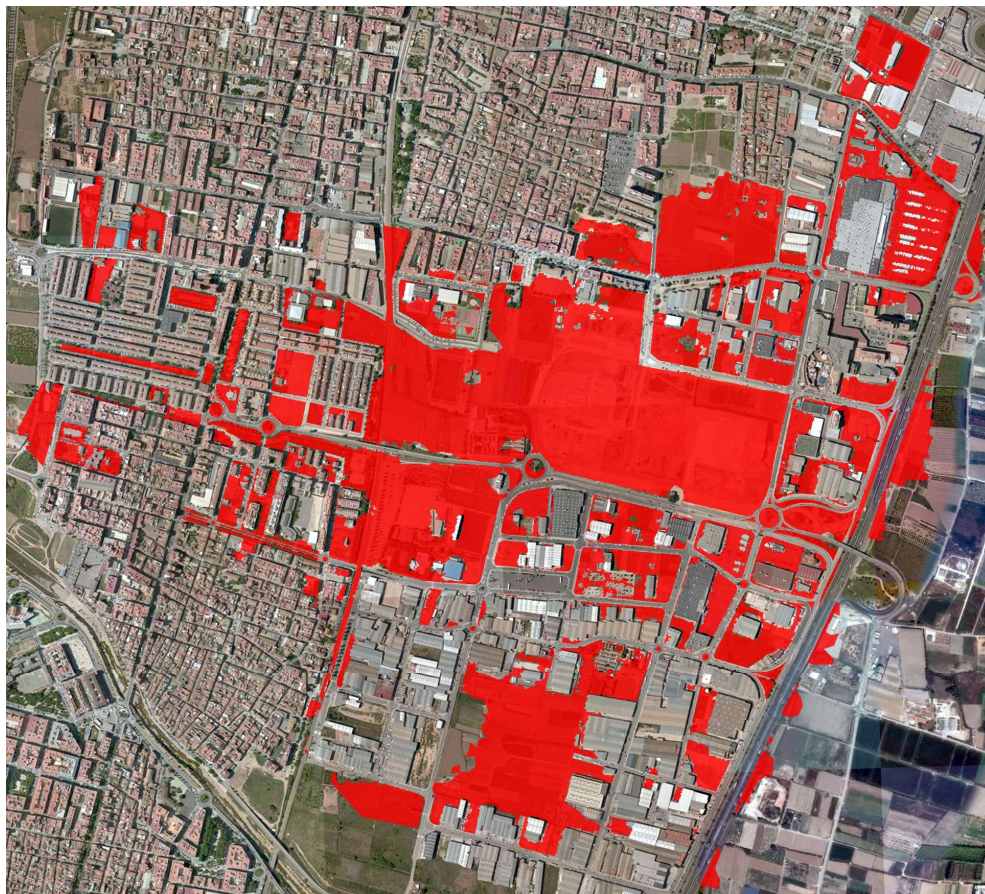
- At a given point of the territory (pixel) and for each type of vehicle  $i$ , the **damage function** should be based on the stability criterion
- Our simplification:

$$D [ S_i (h,u) ] =$$

$$\left\{ \begin{array}{ll} 0 \text{ (stable)} & \text{if } 0 \leq S_i < 1 \\ 1 \text{ (unstable)} & \text{otherwise} \end{array} \right.$$

Stability Thresholds for Studied Vehicles in Flood Events





Low Density (in red) = 5.4 Car/Ha  
High Density = 313.8 Car/Ha\_street

- It is defined at a given point of the territory (pixel) and is measured as the **mean number of vehicles washed away per year per unit area**
- It can be estimated as:

$$r = \sum_{i=1}^K d g_i \int_0^1 D(s_i) dF_{S_i} = \sum_{i=1}^K d g_i \int_0^{\infty} D(s_i) f_{S_i}(s) ds$$

where:

$D(s_i)$  = damage function for car type  $i$ ,  $i = 1, \dots, K$

$d$  = density of vehicles in this pixel

$g_i$  = proportion of car type  $i$

□ And can be approximated by:

$$r = \sum_{i=1}^K d g_i \sum_{j=Tmin}^N D(s_i) \left( \frac{1}{T_{j-1}} - \frac{1}{T_j} \right)$$

where:

$D[h,u,i]$  = damage function for car type  $i$ ,  $i = 1, \dots, K$

$d$  = density of vehicles in the pixel

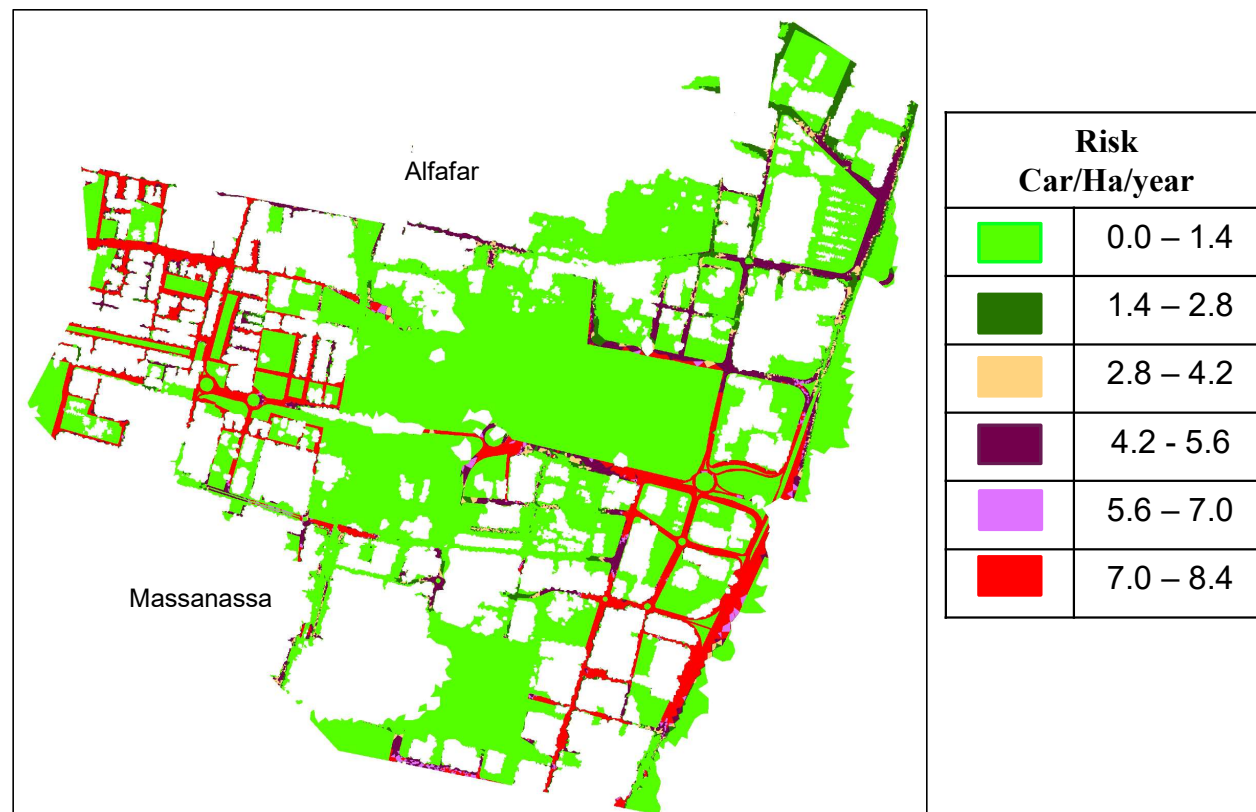
$g [i]$  = proportion of car type  $i$

$j$  = flood hazard map for return period  $T_j$ ,  $j = 1, \dots, N$

**Tmin** corresponds to the lowest return period for inundation

## Mean number of vehicles washed away per year

| Type of car        | gi    | Cars/year    |
|--------------------|-------|--------------|
| Utility            | 0.262 | 71.9         |
| Compact            | 0.322 | 86.3         |
| Small SUV          | 0.148 | 37.9         |
| Medium SUV         | 0.268 | 65.9         |
| <b>Total Fleet</b> |       | <b>262.0</b> |



**18,205 cars within the flooded area**      **Tmin= 37.5 years**









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