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HydroPredict' 2010

Uncertainty assessment for long-term forecasting of extreme values in streamflow due to catchment changes in a Mediterranean mountainous watershed in Southern Spain

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DFH Dinámica Fluvial e Hidrología
UNIVERSIDAD DE CÓRDOBA

DINÁMICA AMBIENTAL
Grupo de Investigación de Dinámica de Flujos Ambientales

Dinámica Fluvial e Hidrología
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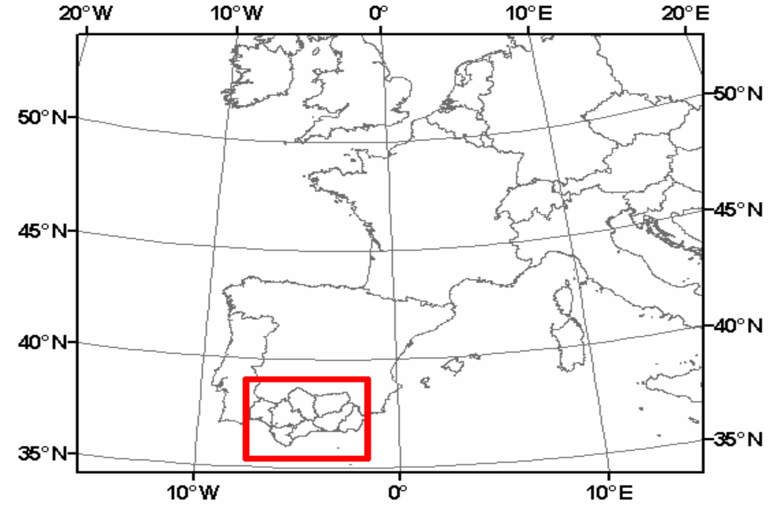

Andalusian Regional Government financed in 2002 a pilot project for

Water Integrated Management

A tool for diagnosis and prognosis of the system behavior in time and space

The Guadalfeo Project

- *Integral watershed modelling*
- *Temporal and spatial scales*
- *Uncertainty asessment*

Soil use and climate scenarios, associated water demands and returns → ***Decission making on water resources based on risk analysis***

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Risk analysis and decision making

Risk = Probability of "failure" x Associated cost

Total cost = $\sum$ partial costs =
=damage and repair + opportunity costs + environmental costs

(European Water FrameWork Directive)

Failure= Situation where our goals are not achieved

Decision making based on minimizing risk

Objectives:

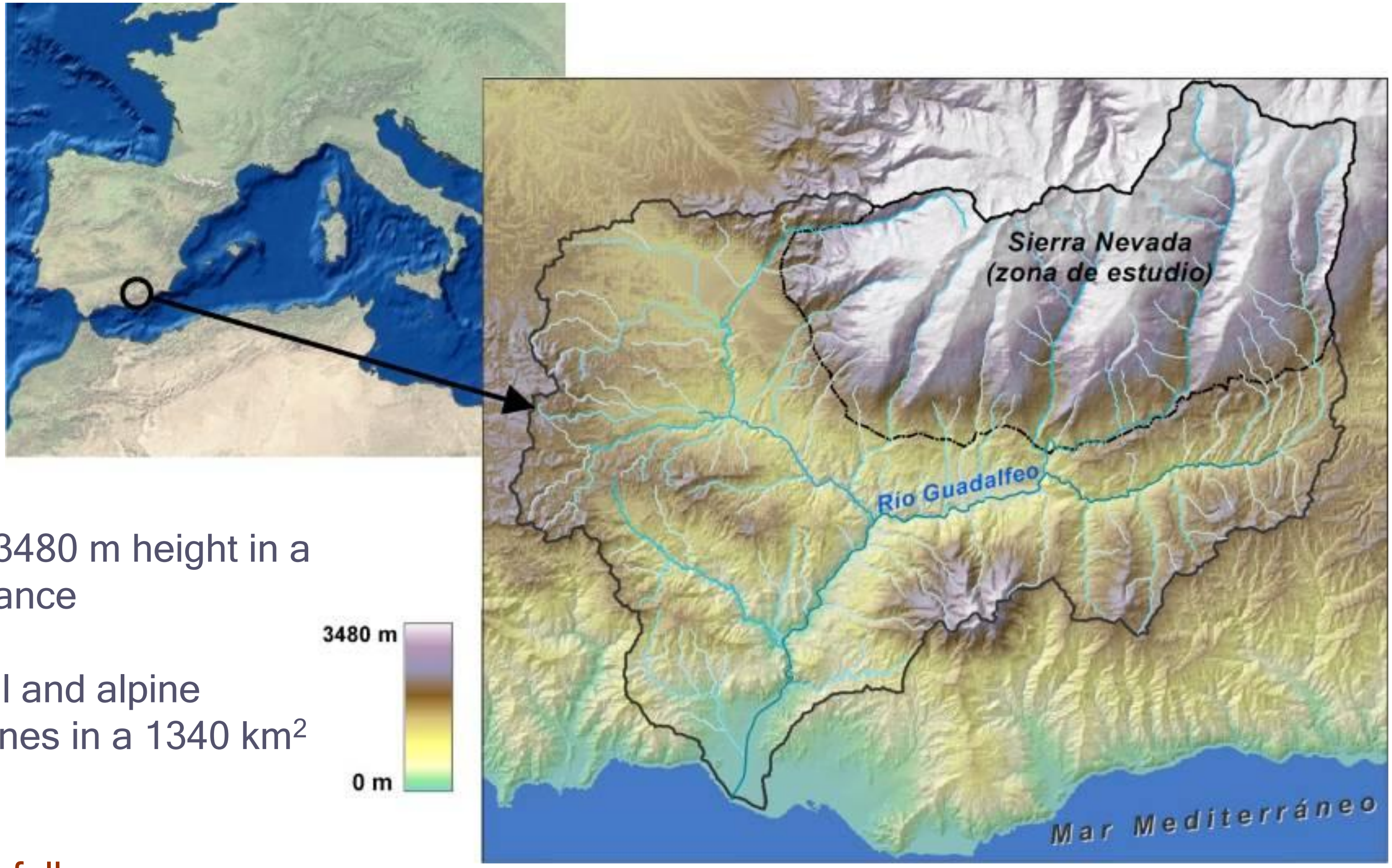
To provide with a methodology for uncertainty assessment based on probabilistic forecasting enhanced by the use of a physically based hydrological model:

Quantifying the reference variability of hydrological regimes in Mediterranean watersheds
Quantifying uncertainty of derived variables
Quantifying uncertainty under changes in the catchment area

Oriented to risk analysis as a decision making tool

Index

1 Study site



From 0 to 3480 m height in a 70 km distance

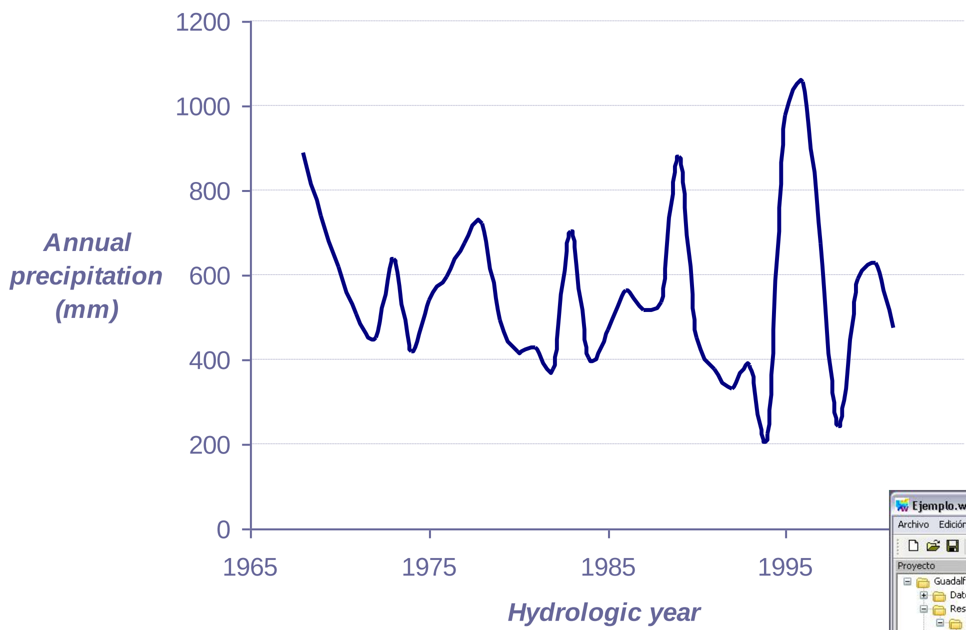
Subtropical and alpine climatic zones in a 1340 km^2 area

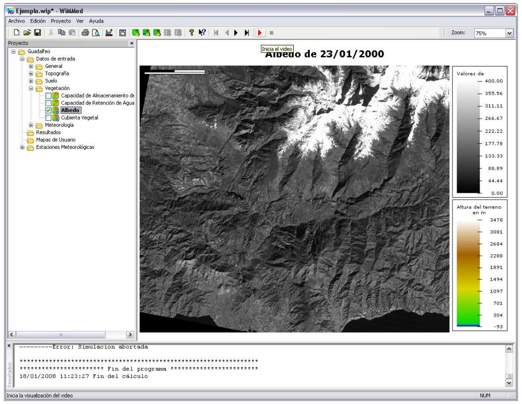
Annual rainfall averages 570mm, runoff greatly influenced by snow

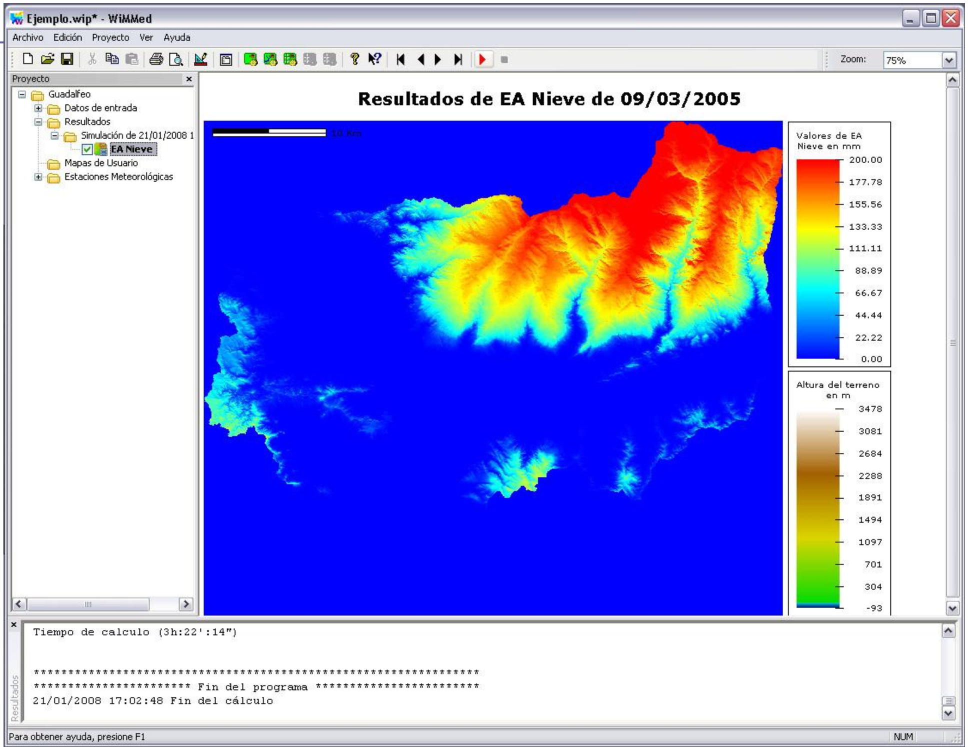
www.cuencaguadalfeo.com (in Spanish)

Uncertainty assessment for long-term forecasting of extreme values in streamflows due to catchment changes in a Mediterranean mountainous watershed in Southern Spain

1 Study site







1 Study site

In 2002, a new dam was constructed in the main course of the Guadalfeo River

....

2 Uncertainty assessment

Main uncertainty sources in runoff calculations:

Input variables

Occurrence of rainfall events, and their characteristics

Measurement error at stations

Interpolation algorithm

Input parameters

Characterization of the physical/experimental parameters that describe the system and its modelling

Measurement error

Model structure

Mathematical formulation of each submodel and their connections

Spatiotemporal resolution of the state variables

By "control" of the rest of sources, the occurrence of rainfall accounts for more than 96% of the variability in this area (Polo *et al.*, 2006)

2 Uncertainty assessment

Available multivariate data series of “events” and “non- events” = *V* years

↓

Probability distribution functions of the input variables

This single sample is replicated N times by resampling using a Weather Generator oriented to Mediterranean conditions validated at the study site (Nieto *et al.*, 2006)

Empirical/analytical pdfs of the input variables → Weather Generator (Monte Carlo simulation of multivariate variables) → N samples of V years of meteorological sequences

↓

Validation of pdfs and extreme variables in V years pdfs

2 Uncertainty assessment

Soil use distribution, water demands, system operation

GIS definition of the environment, and parameter values in the governing equations

Resampling: 1 event, v events, season, year, V years… by the Weather Generator

Results: N groups made up by1 event, or v events, or 1 season, or 1 year, or V years

Watershed distributed physical/ global models

(WiMMed software, 2010)

N groups of results for the A state variables previously selected

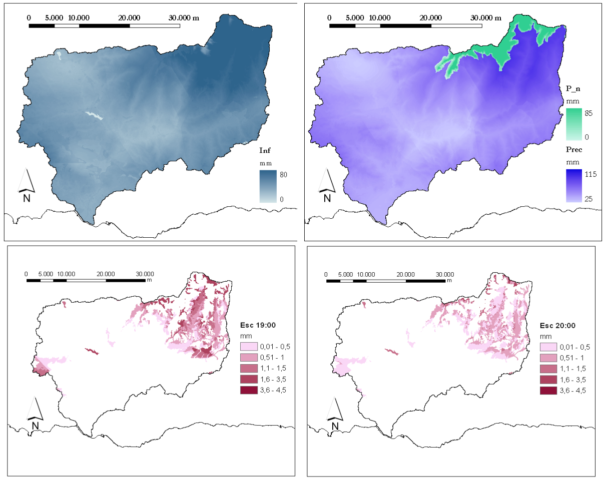
Probability distribution functions for each A variable and theirjoint combination (marginal, conditional, joint… distributions)

Available information at the study site

- 40 year series of daily meteorological variables at 32 stations
- 10 year series of 30 min meteorological variables at 5 stations
- 5 year of field data about snow conditions (from 2003 on)
- 30m DEM from Andalusian Regional Cartography
- Soil characteristics cartography (LUCDEME Project)
- Soil use and forests (CORINNE, and Andalusian Regional Cartography
- 15 year series of daily streamflow at 5 gauge stations upwaters (with gaps)
- Vegetation cover fraction seasonal evolution by Landsat data analyses (8 year)

Hydrological /hydraulic simulation of the 40 year historical period by WiMMed (calibration/validation by the research group in the Guadalfeo Project: Herrero, 2005, 2007; Millares, 2006, 2008; Aguilar, 2006, 2008; Ávila, 2006, 2008; Díaz-Gutiérrez, 2007)

Herrero *et al.*, 2009, Millares *et al., 2009;*
Aguilar *et al.,* 2010
Aguilar *et al*., Millares *et al*., Polo *et al*., under revision



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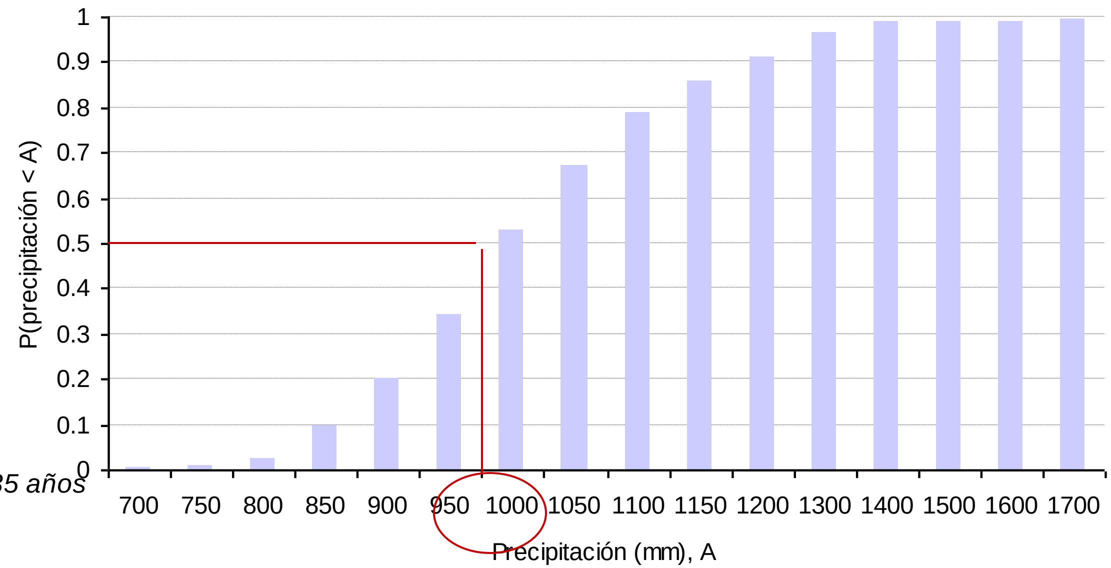
3 Results: Extreme variables regime

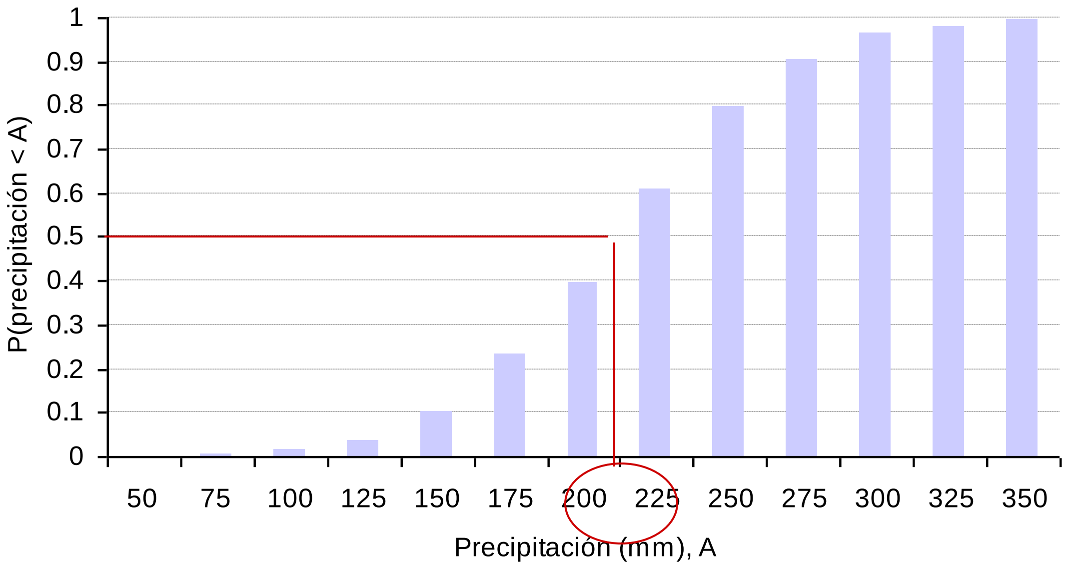
Some examples of extreme variables simulated pdfs:

Maximum and minimum annual precipitation in 35 years (N=250)

Precipitación anual máxima en grupos de 35 años



Precipitación anual mínima en grupos de 35 años

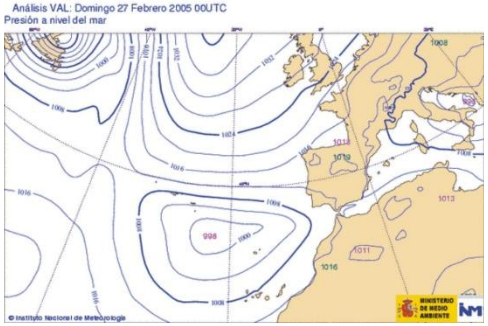


Reference results to compare with GC scenarios

3 Results: Derived variables forecasting

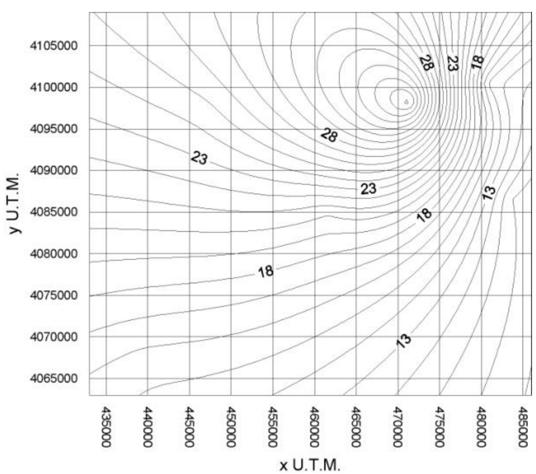
Physical models cascade diagram for streamflow

Cyclonic front

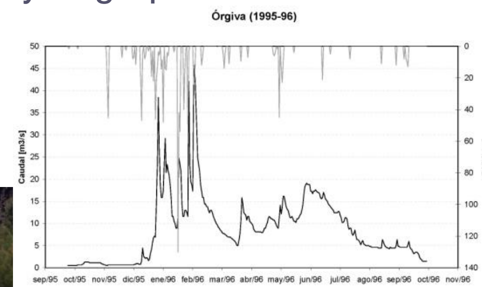


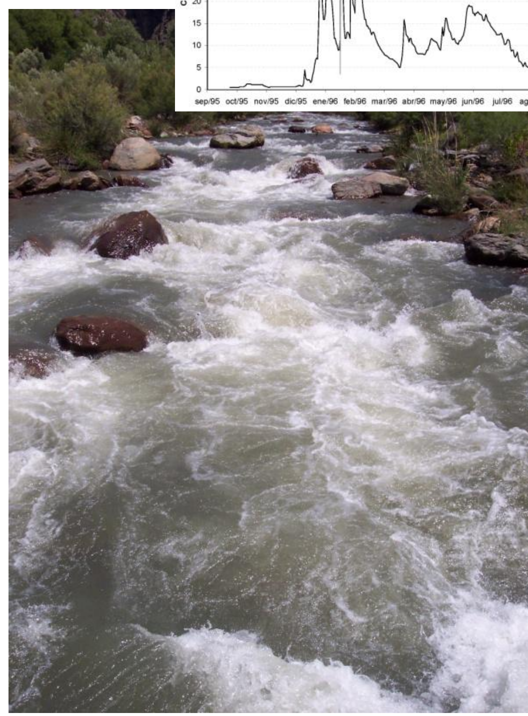
Type and definition

Rainfall pattern



Hydrographs





Water excess circulation

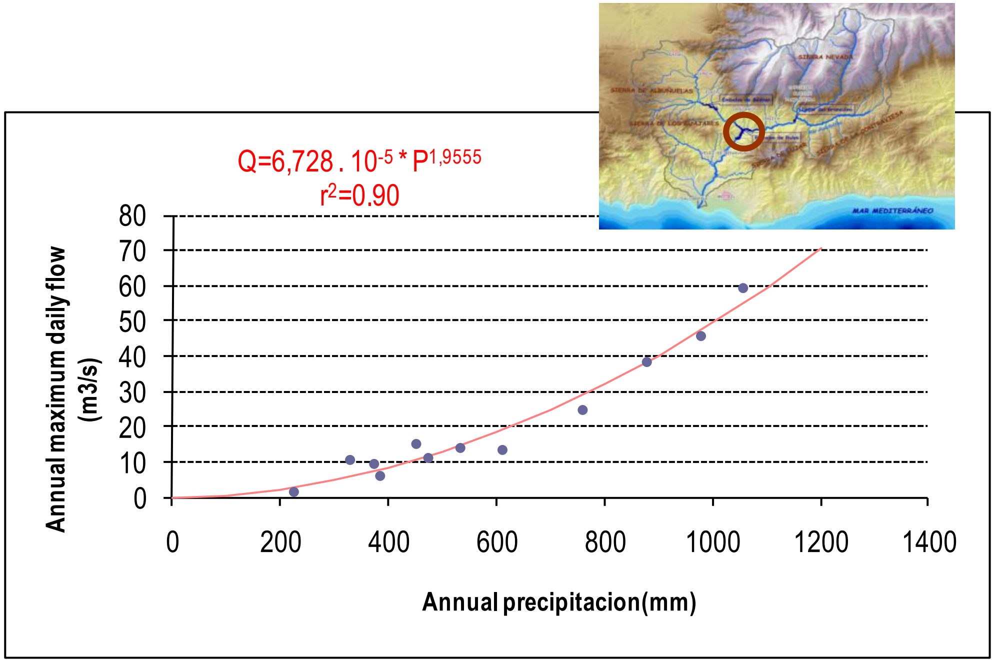
Hydraulic model

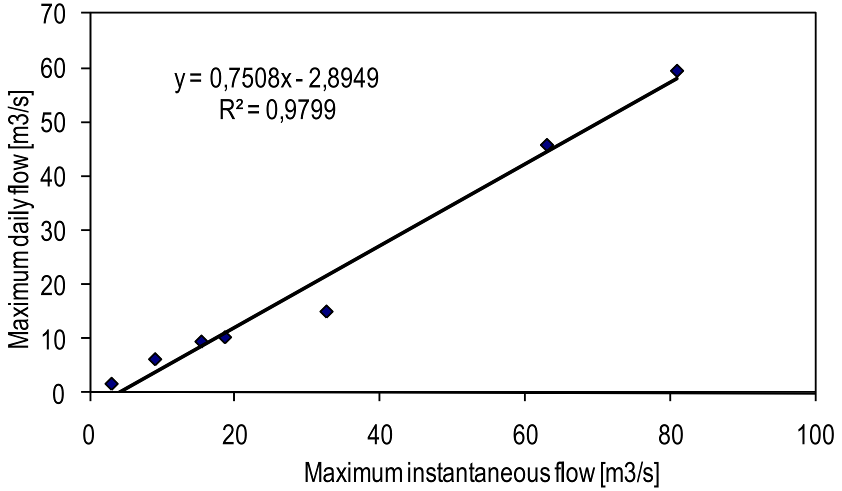
Maximum instantaneous flow along the river channel for each simulated group of V years,

and associated variables: water level, speed, and flooding plain

3 Results: Derived variables forecasting

Derived pdfs for maximum instantaneous water flow:

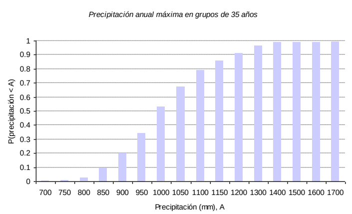


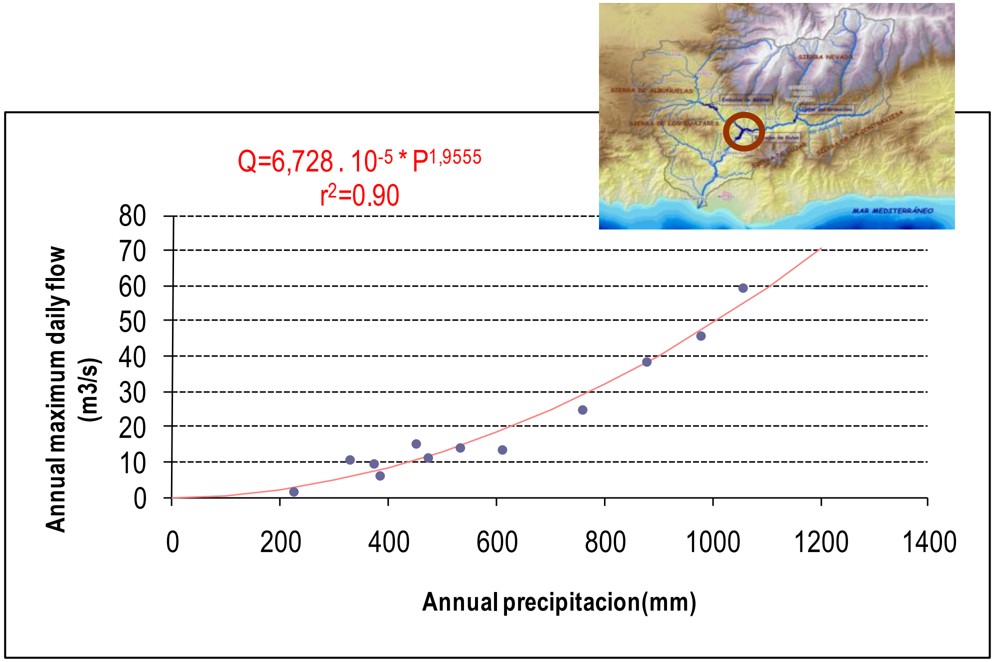


3 Results: Derived variables forecasting

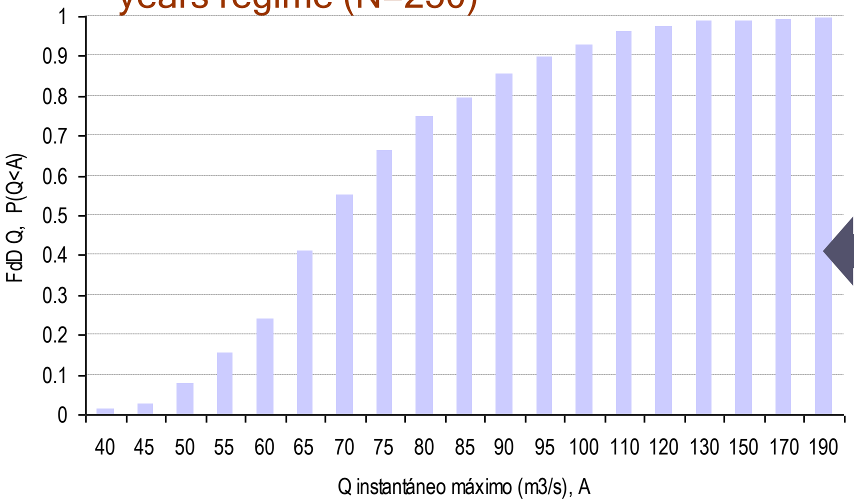
Derived pdfs for maximum instantaneous water flow:

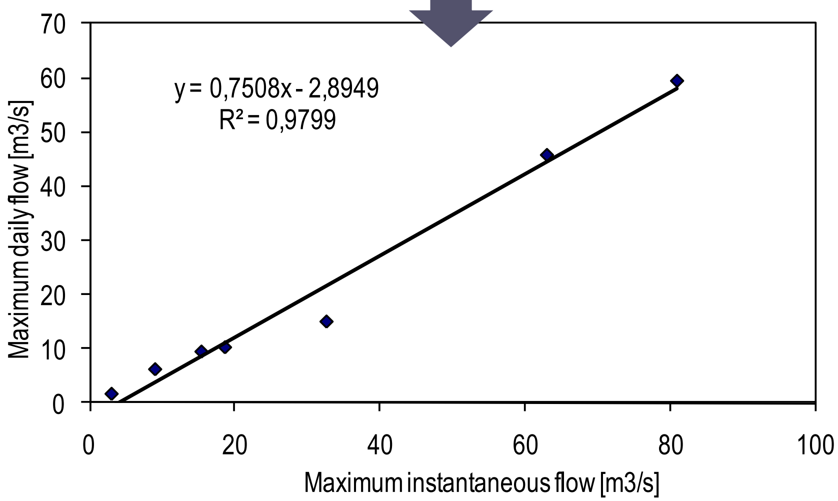
Maximum annual precipitación in 35 years regime (N=250)





Maximum instantaneous flow in 35 years regime (N=250)





3 Results: Derived variables forecasting

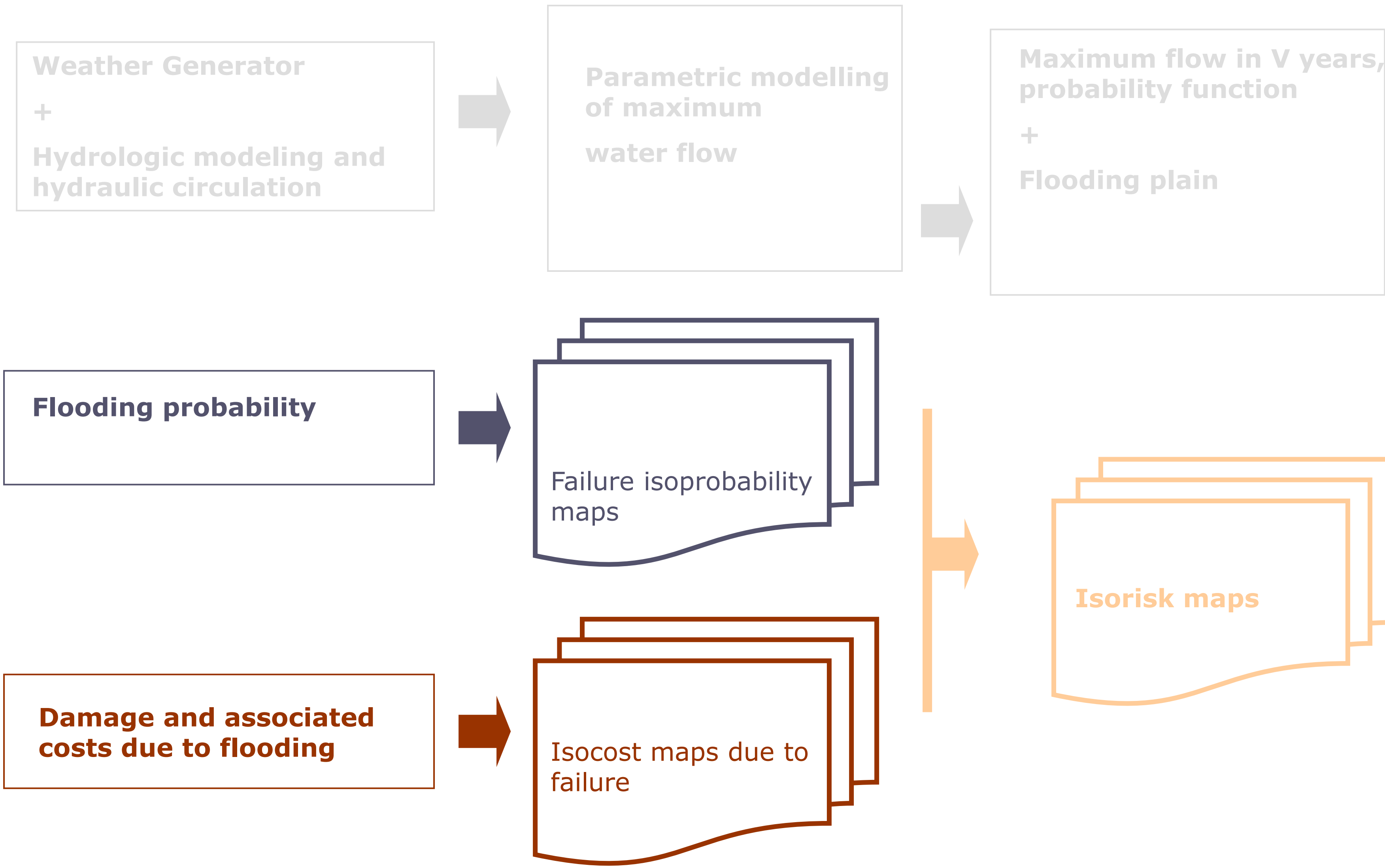
Derived flood vulnerability in 35 years:

Q=40 m^3/s at Órgiva (p=0.99)

Q=190 m^3/s at Órgiva (p=0.01)

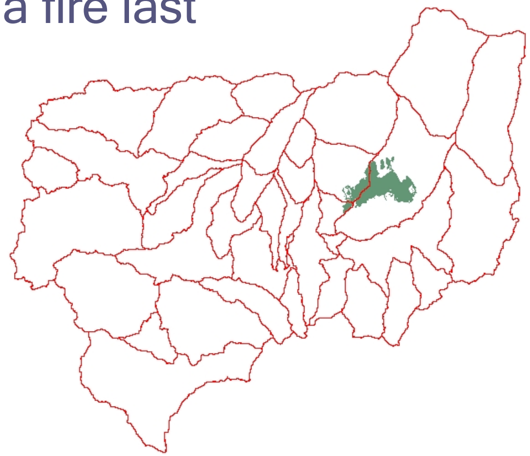
3 Results: Derived variables forecasting

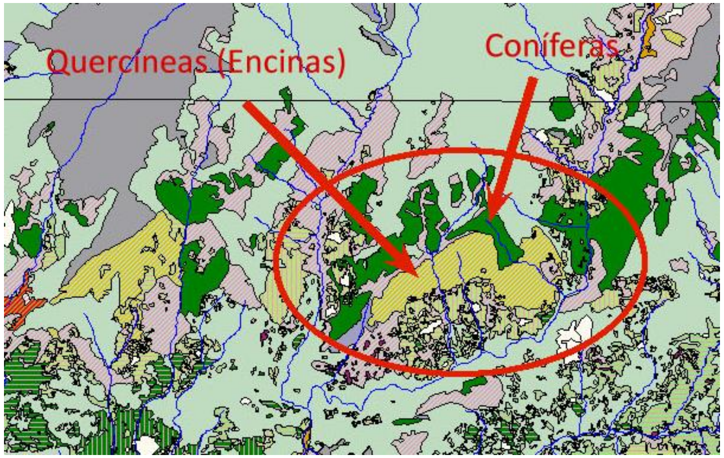
Flooding risk analysis

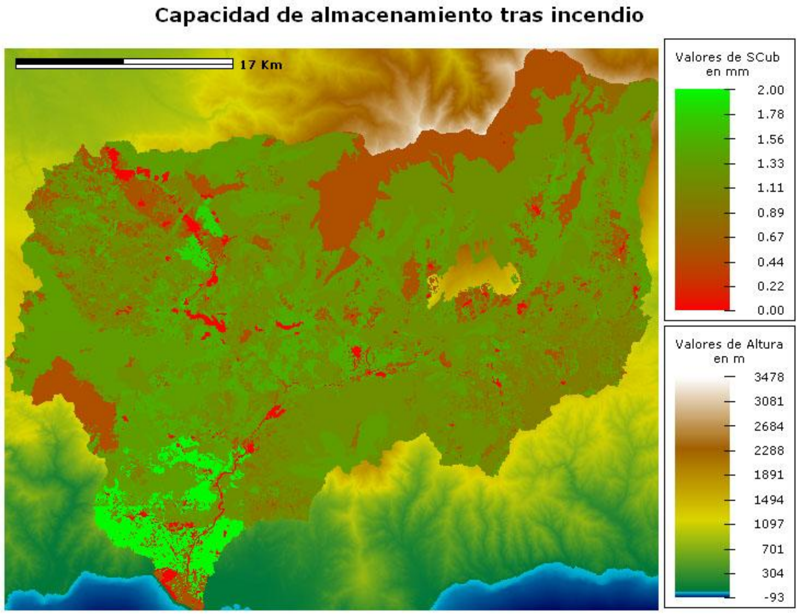


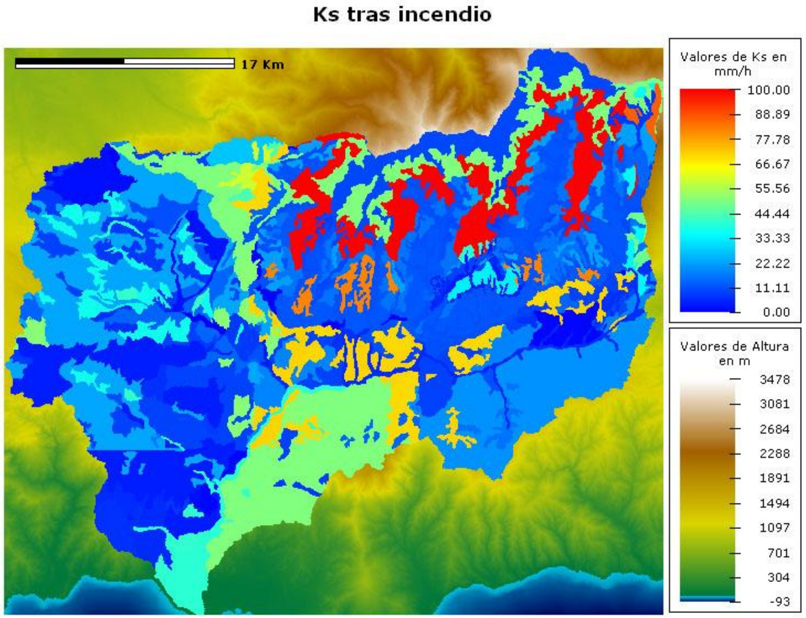
3 Results : Simulated scenario

Simulation of a fire last summer



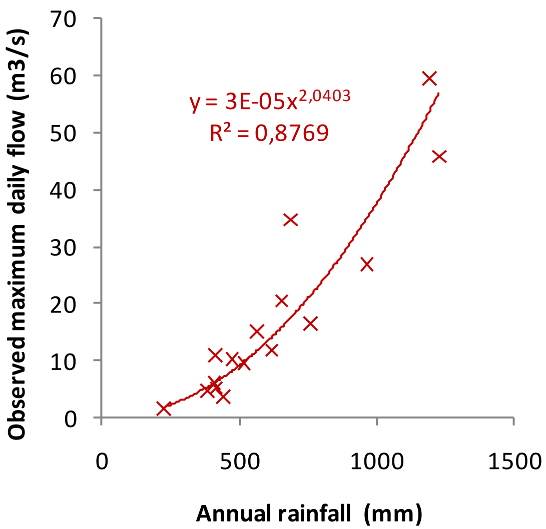


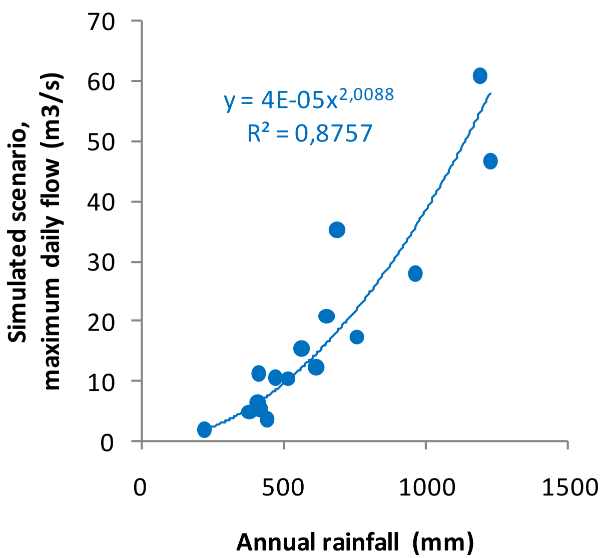




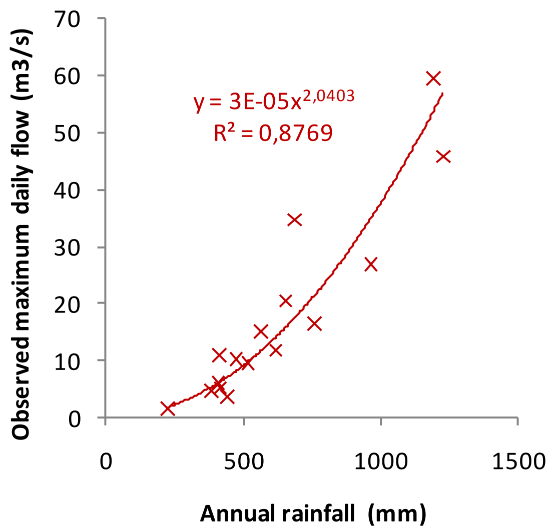
3 Results: simulated scenario

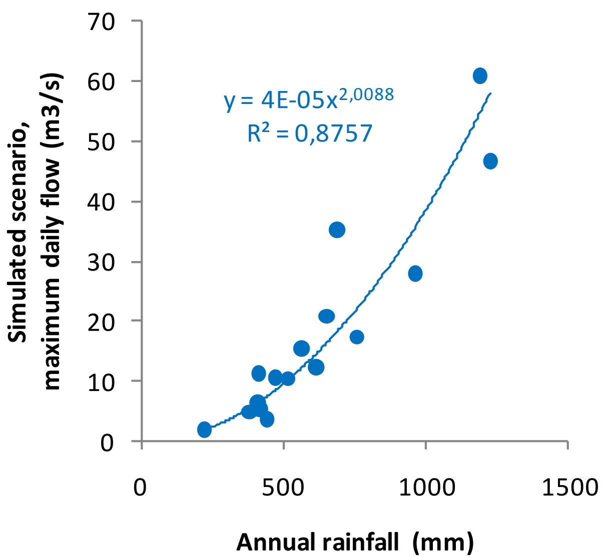
Maximum flow prediction next year?



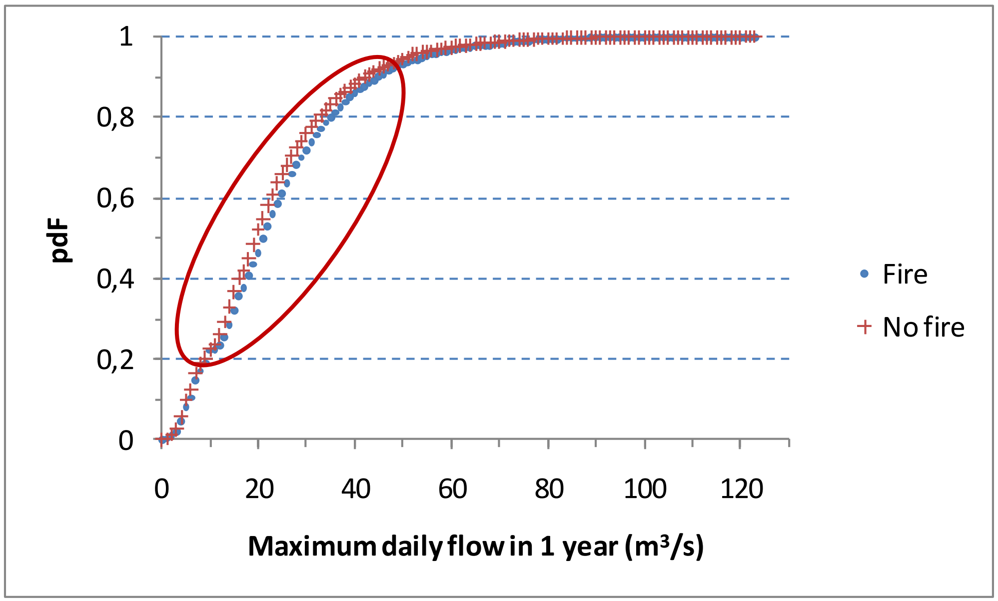


3 Results: simulated scenario

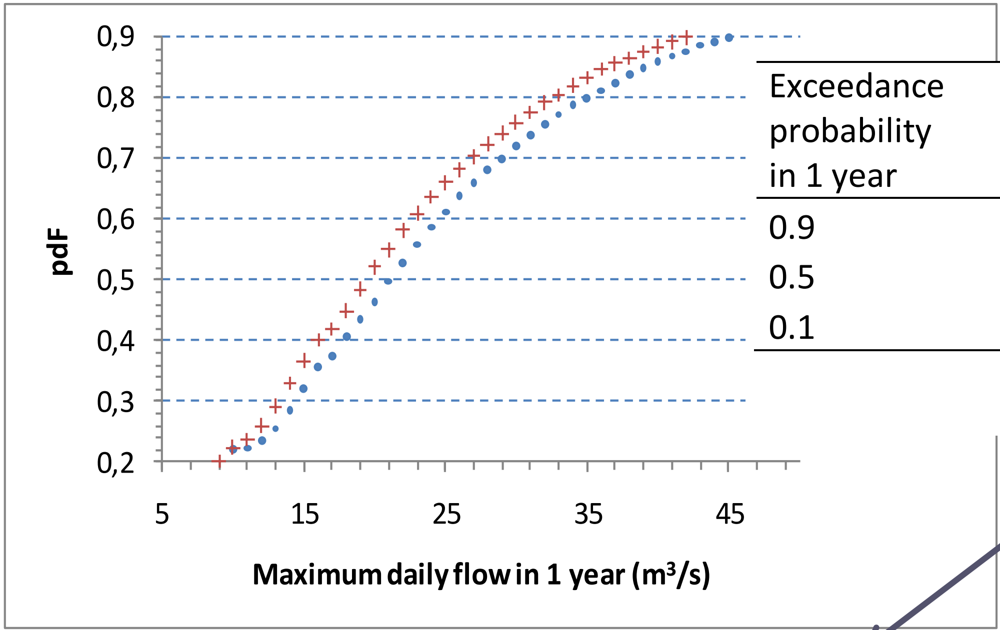




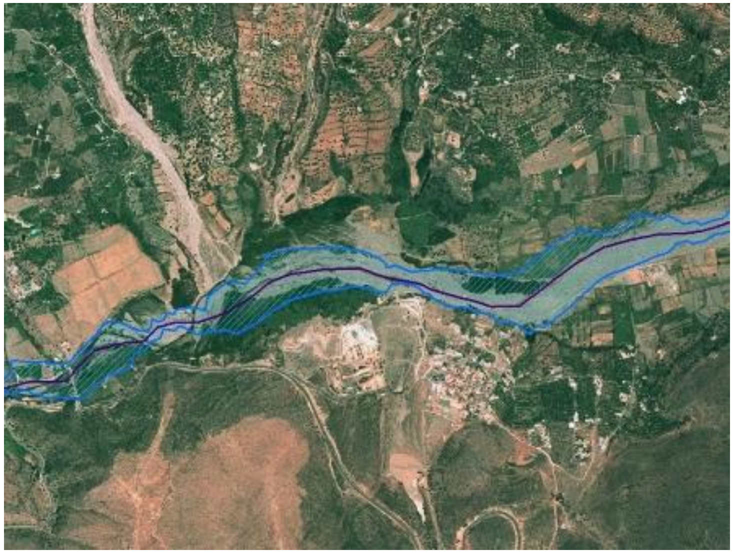
Maximum flow prediction next year?



3 Results: Simulation of scenario



Exceedance probability in 1 year	No fire (obs.) Daily	No fire (obs.) Inst.	Fire (sim.) Daily	Fire (sim.) Inst.
0.9	4.1	**9.3**	4.3	**9.6**
0.5	19.8	**30.2**	21.2	**32.1**
0.1	42.0	**59.8**	45.1	**63.9**



4 Conclusions

On the Mediterranean variability of extreme meteorological variables

The methodology proposed provides with reference variability regimes once the Weather Generator is locally validated.

On the derived variables forecasting

The availability of validated coupled hydrologic and hydraulic models allows a good aproximation to a probabilistic forecasting of derived variables, such as flooding vulnerability characterization.

On the catchment change scenarios

The availability of validated coupled hydrologic (distributed physically-based) and hydraulic models provides us with a tool to forecast such effects which, combined with the Weather Generator, allows a probabilistic approach to be included in risk analysis

RISK ANALYSIS AS DECISION MAKING SUPPORT SYSTEM

On-going work

Calibration / Validation of sediment and nutrient/pollutant fluxes

Inclusion of erosive and water quality modules , reservoir operation module, and uncertainty assessment in the Windows interface of WiMMed

Transference of the model to the regional water administration

Acknowledgments

This work is funded by the Andalusian Water Agency (Regional Government).

The so-called "Guadalfeo Project" and its renewals are the result of a multidisciplinary team of researchers from the Universities of Cordoba and Granada; some aspects have been resumed and presented here by the authors, but it would have not been possible without the work from:

Cristina Aguilar, Alberto Ávila, Javier Herrero, Agustín Millares, Antonio Moñino, and Sergio Nieto

But other collaborations throughout the Project must be mentioned here: Alejandro Ruiz-Lazcano, Marta Egüen, Isabel Moreno, Eva Contreras, and Raquel Gómez-Beas.

Asunción Baquerizo's collaboration in the uncertainty analysis is especially appreciated.

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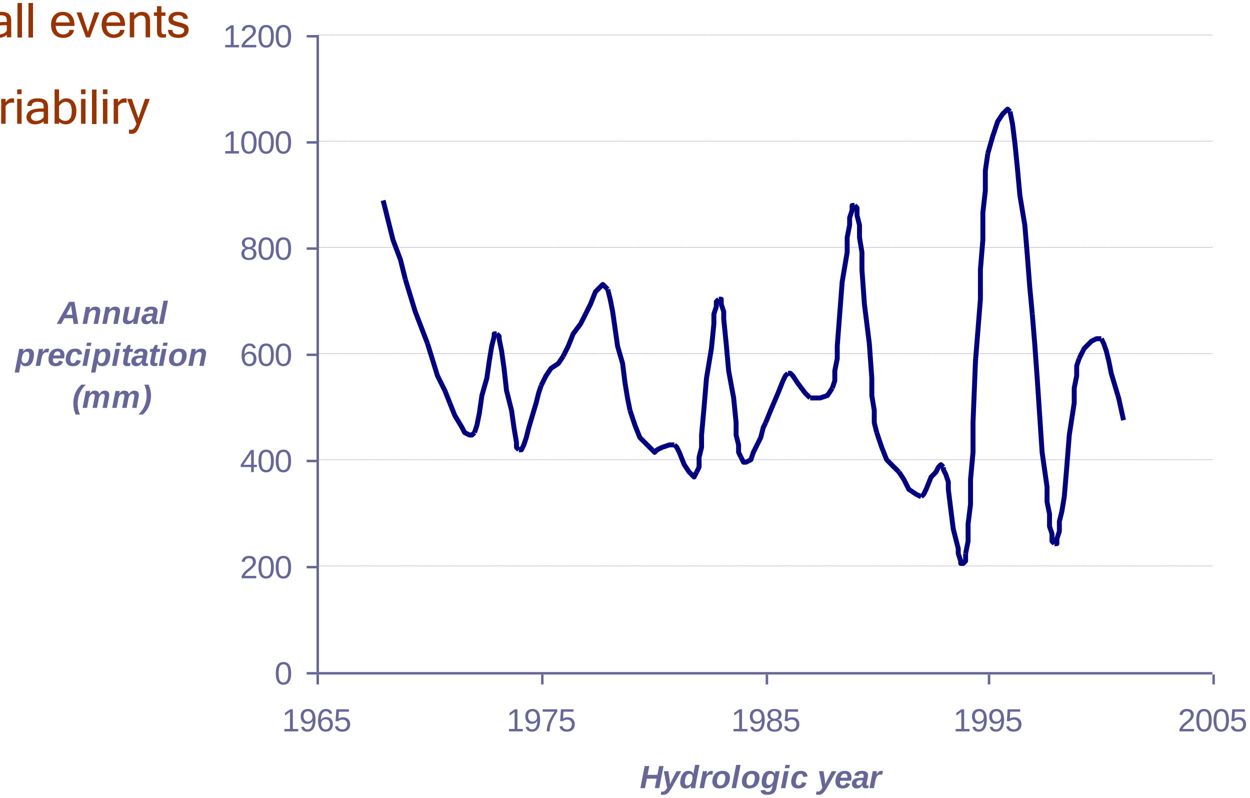
THANK YOU ALL!


Thank you for your attention!

Some usual features of *Mediterranean watersheds*

- Topography and morphology gradients
  - Height, slopes, facing...
- Wide range of meteorological conditions
  - Seasonal/annual/pluriannual droughts
  - Torrential rainfall events
  - High annual variabiliry



Some usual features of *Mediterranean watersheds*

- Regulation, flood protection, and singularities

  Reservoirs, aquifers, deltas, ephemeral streams

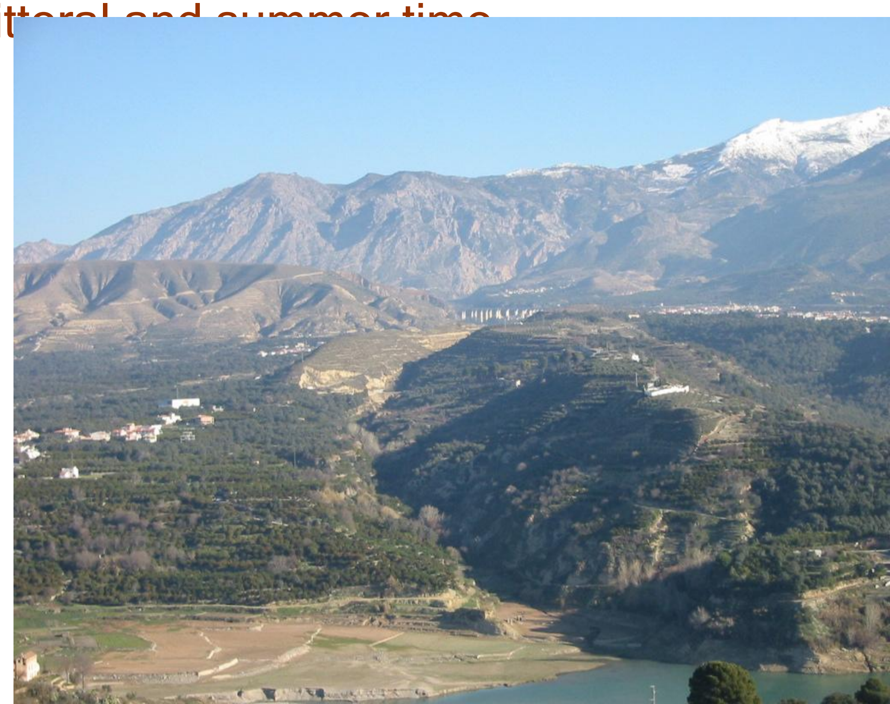
- Crops and natural vegetation in patched areas

  Intensive and irrigated crops

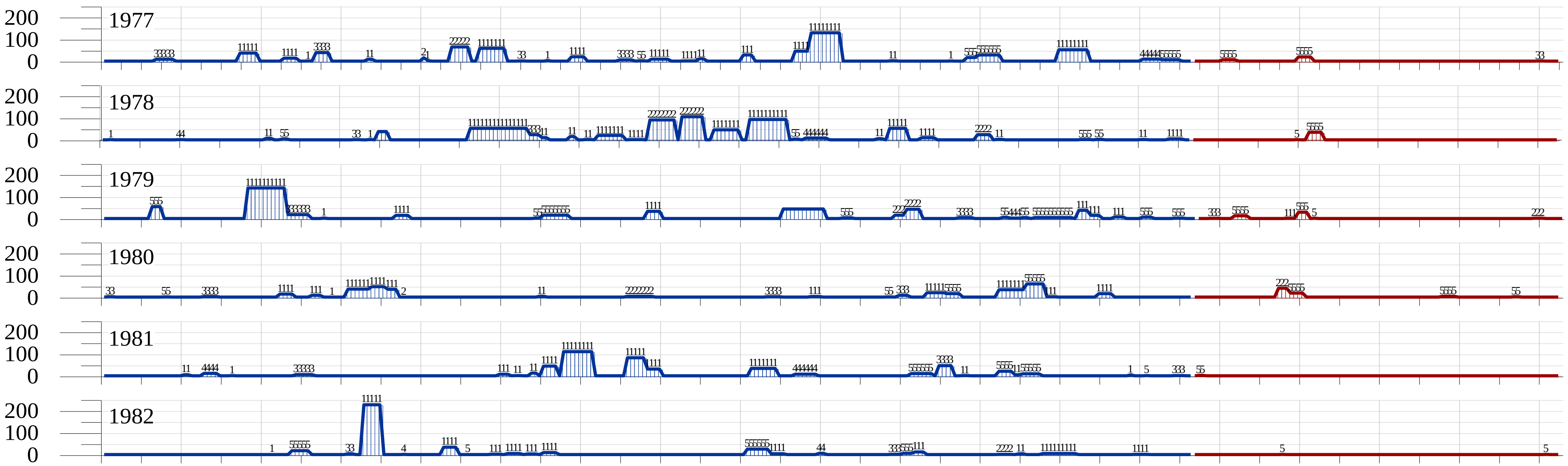
- Urban and touristic development stress on water resources

  Coincident in space and time: littoral and summer time

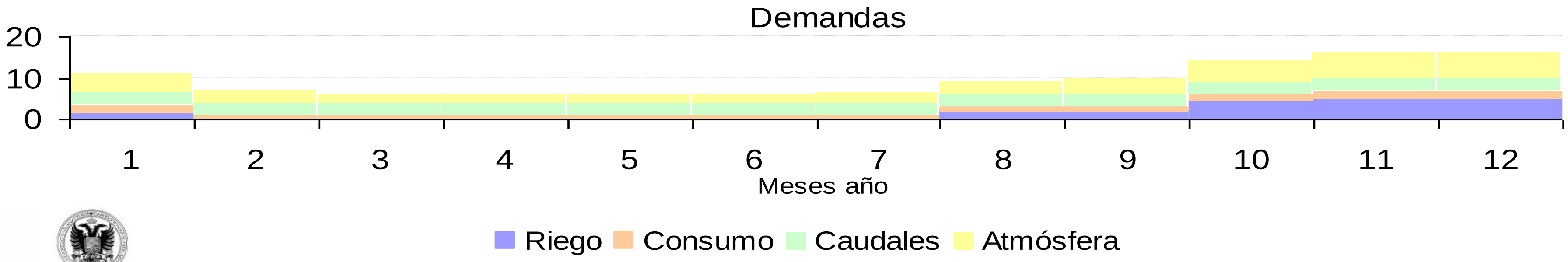
Heterogeneity!!



Some usual constraints of *water resource planning*



Store: supply+fires+floods+...



Some constraints for uncertainty assessment of hydrological variables

•Long time series available for meteorological variables (~O 40-100 years)

Rainfall, temperature >>> radiation components, wind, air humidity

•Medium time series available for streamflow in big rivers (~O 40-60 years)

Ebro, Guadalquivir, Guadiana > Júcar, Segura

Water depth > daily flow >>> water velocity

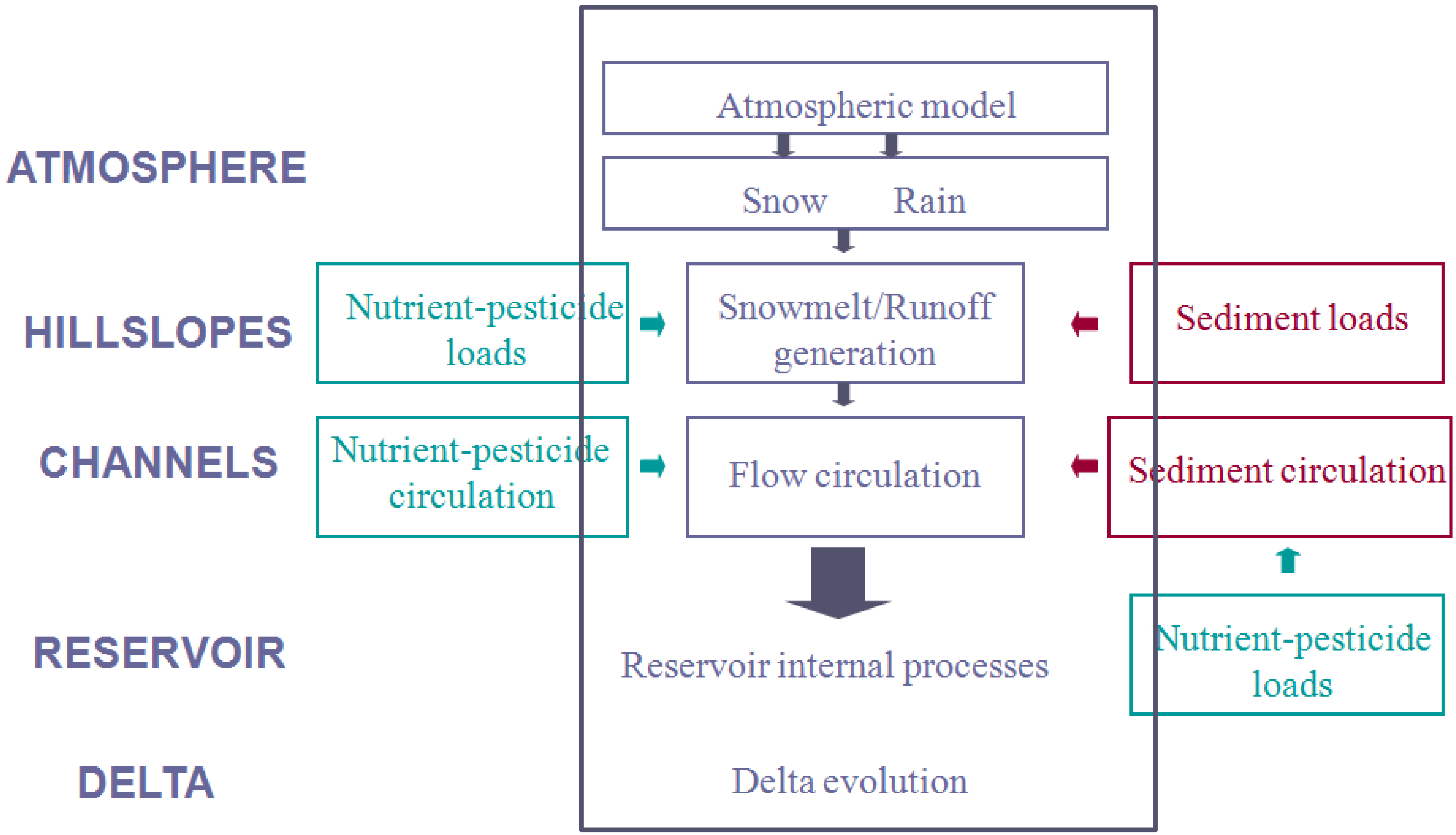
•Short time series available along the fluvial network (~O 10-20 years)

Water depth, inflow to reservoirs

Intermitent/ephemeral rivers (maximum-minimum values)

Prediction of extreme values at different scales

Current Windows interface



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Atmosphere

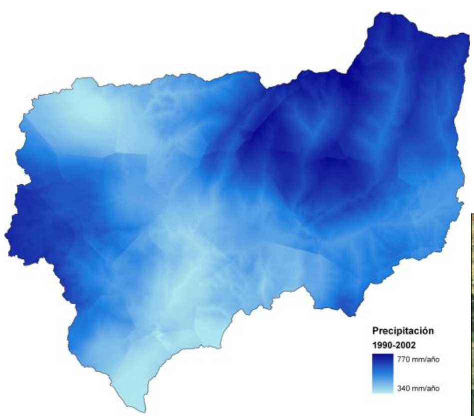
Event (cyclonic front) and non-event definition of states

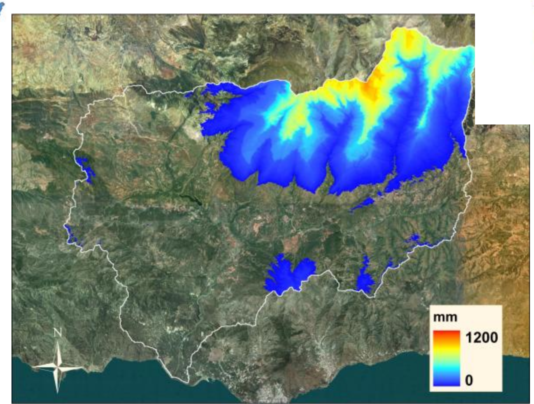
Spatial interpolation algorithms

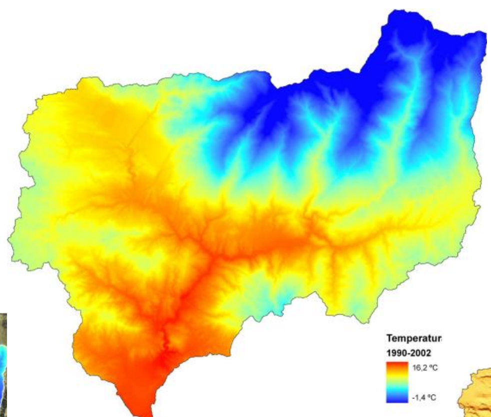
Rainfall	Height corrections
Temperature	Height corrections
Solar radiation	Topographic corrections

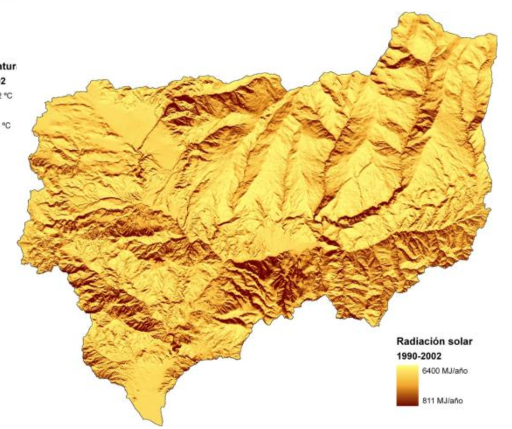
(*Aguilar et al., 2010, HESS., in press*)

Snowfall occurrence









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Hillslopes, energy and water balance (DEM cell)

Variable time resolution depending on process scales

Rainfall interception by vegetation

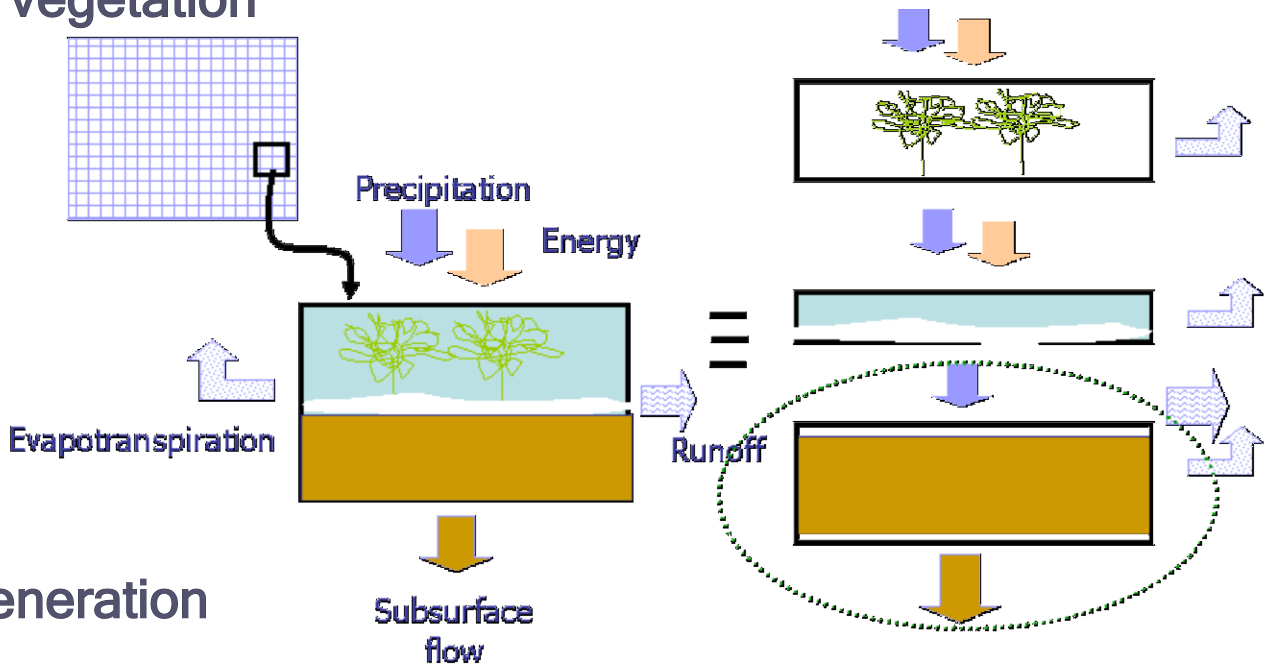
Storage
Throughfall
Evaporation

Snow cover evolution

Accumulation
Fusion
Evaporation

Infiltration and runoff generation

Infiltration
Lateral flow
Recharge
Baseflow
Evaporation



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Hillslopes, energy and water balance (DEM cell)

Rainfall interception by vegetation

- Storage
- Throughfall
- Evaporation

Snow cover evolution

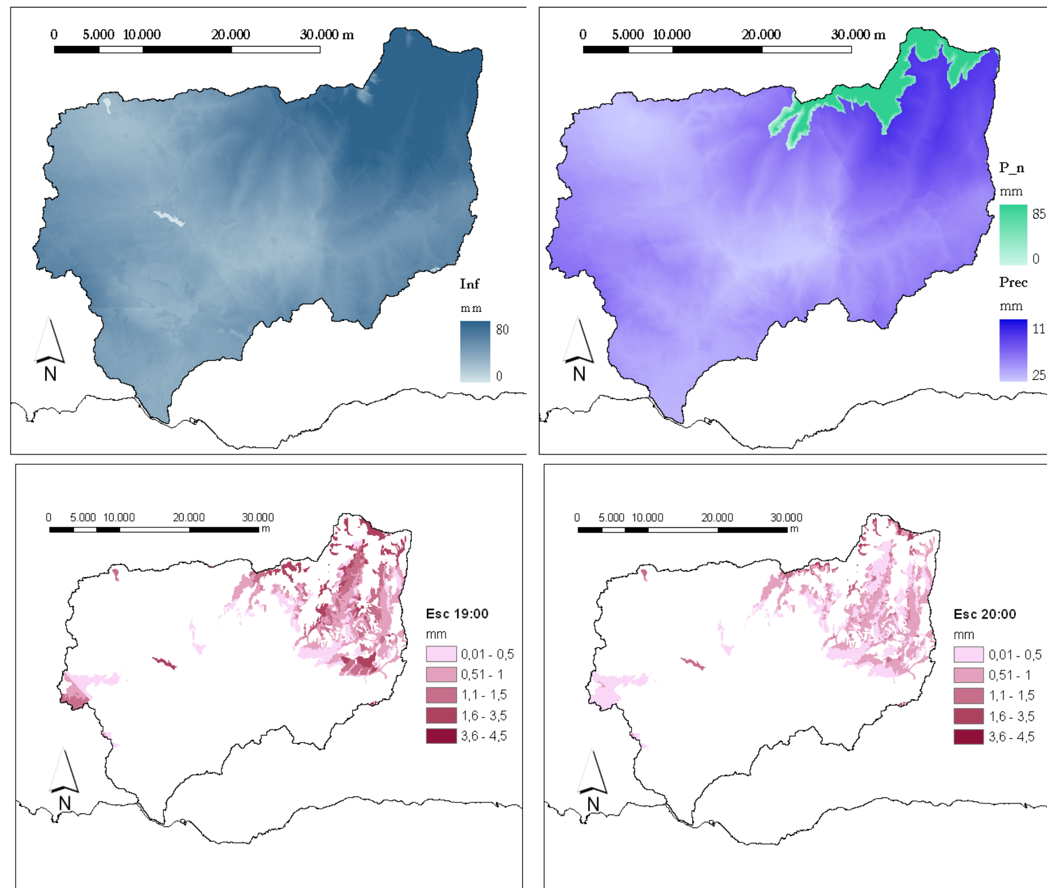
(Herrero et al., 2009, J. Hydrol.)

- Accumulation
- Fusion
- Evaporation

Infiltration and runoff generation

(Millares et al., 2009; HESS)
(Aguilar et al., Millares et al., revision)

- Infiltration
- Lateral flow
- Recharge
- Evaporation
- Baseflow



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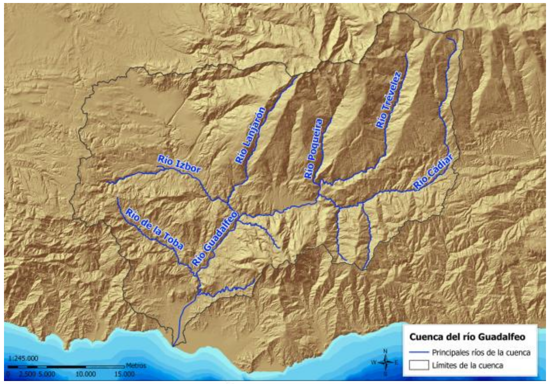
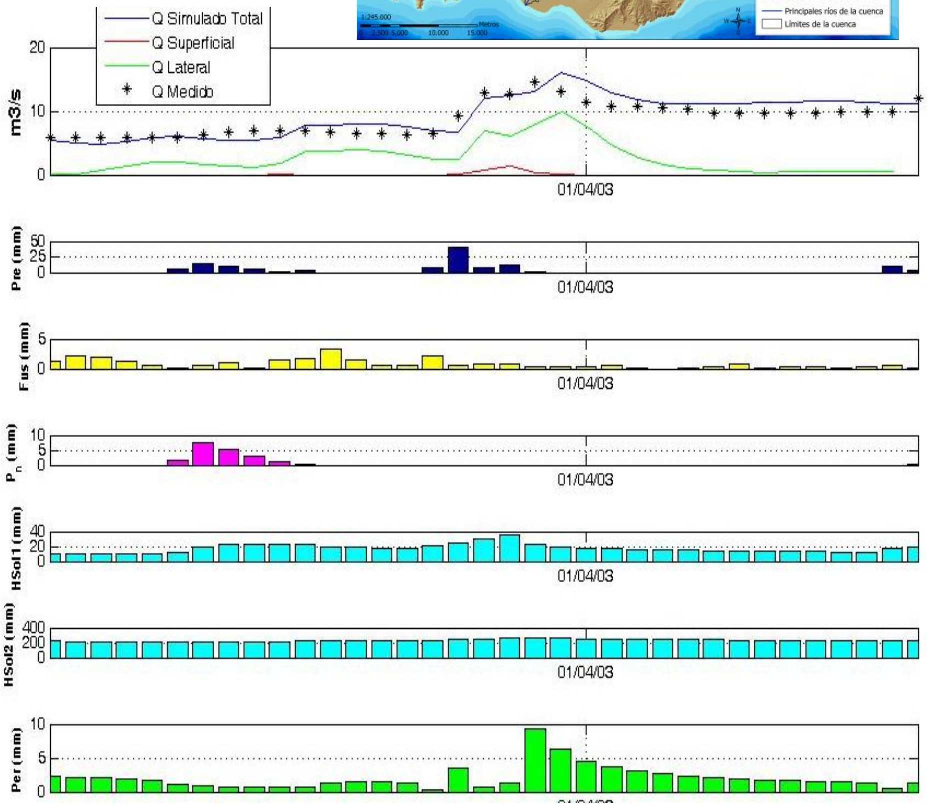
Water circulation (hillslopes and channels)

Variable time resolution depending on process scales



Streamflow hydrographs at control points

Baseflow
Direct runoff



Hillslopes routing

Storms/dry periods (river channels)
Hydrologic routing
Kinematic/diffusive wave

Hydraulic circulation (river channels)

1D hydrodynamic equations
Transient regimes
Floodplains

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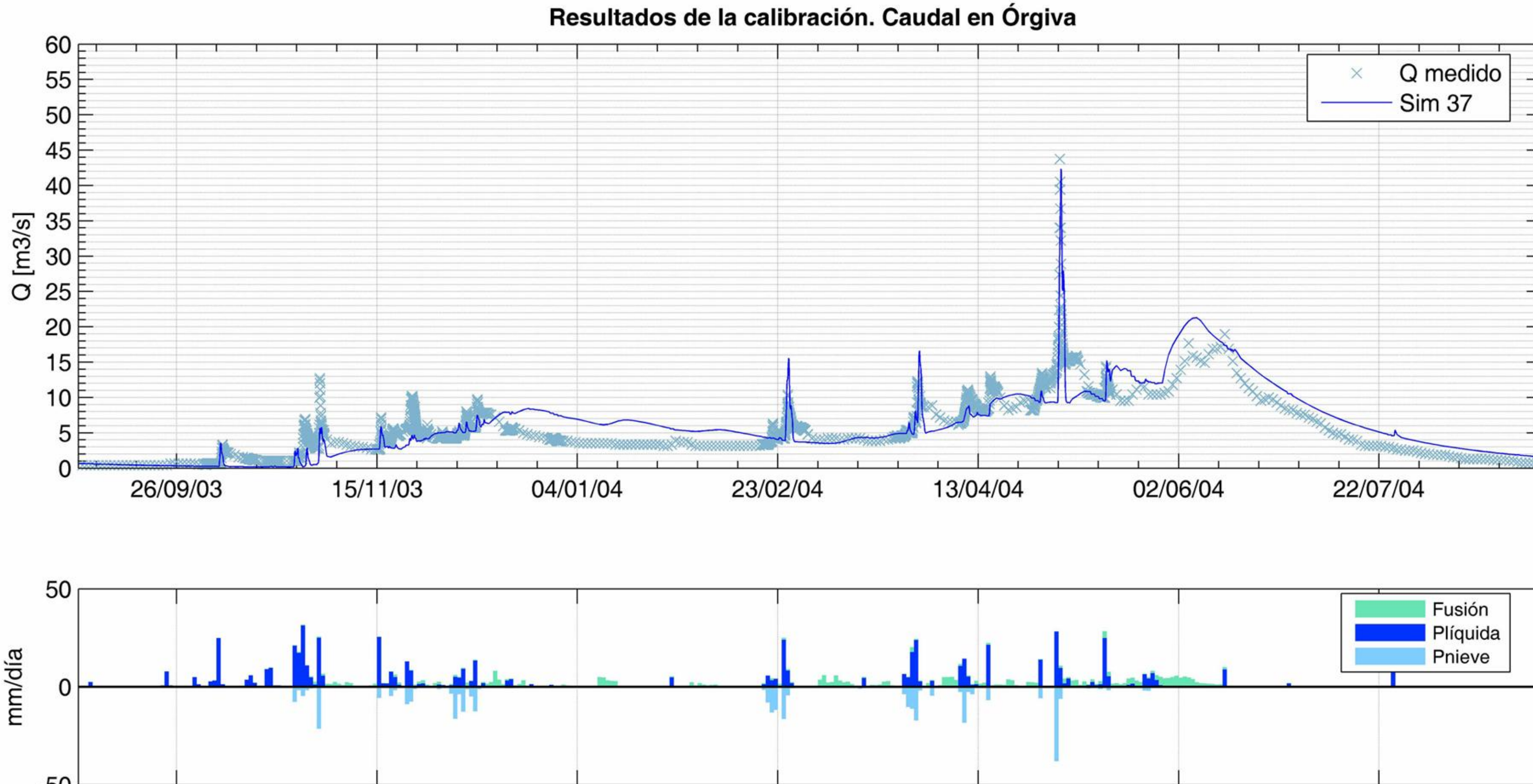
Water circulation (hillslopes and channels)

Variable time resolution depending on process scales



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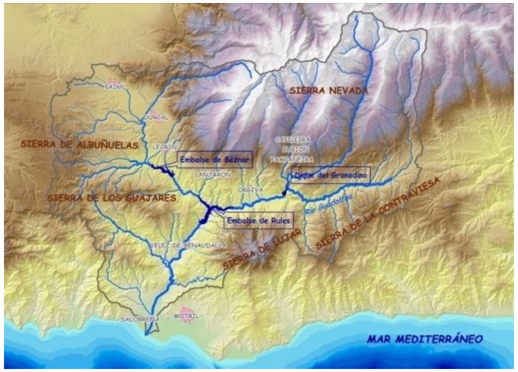
Water circulation (hillslopes and channels)

Variable time resolution depending on process scales



Streamflow hydrographs at control points

- Baseflow
- Direct runoff

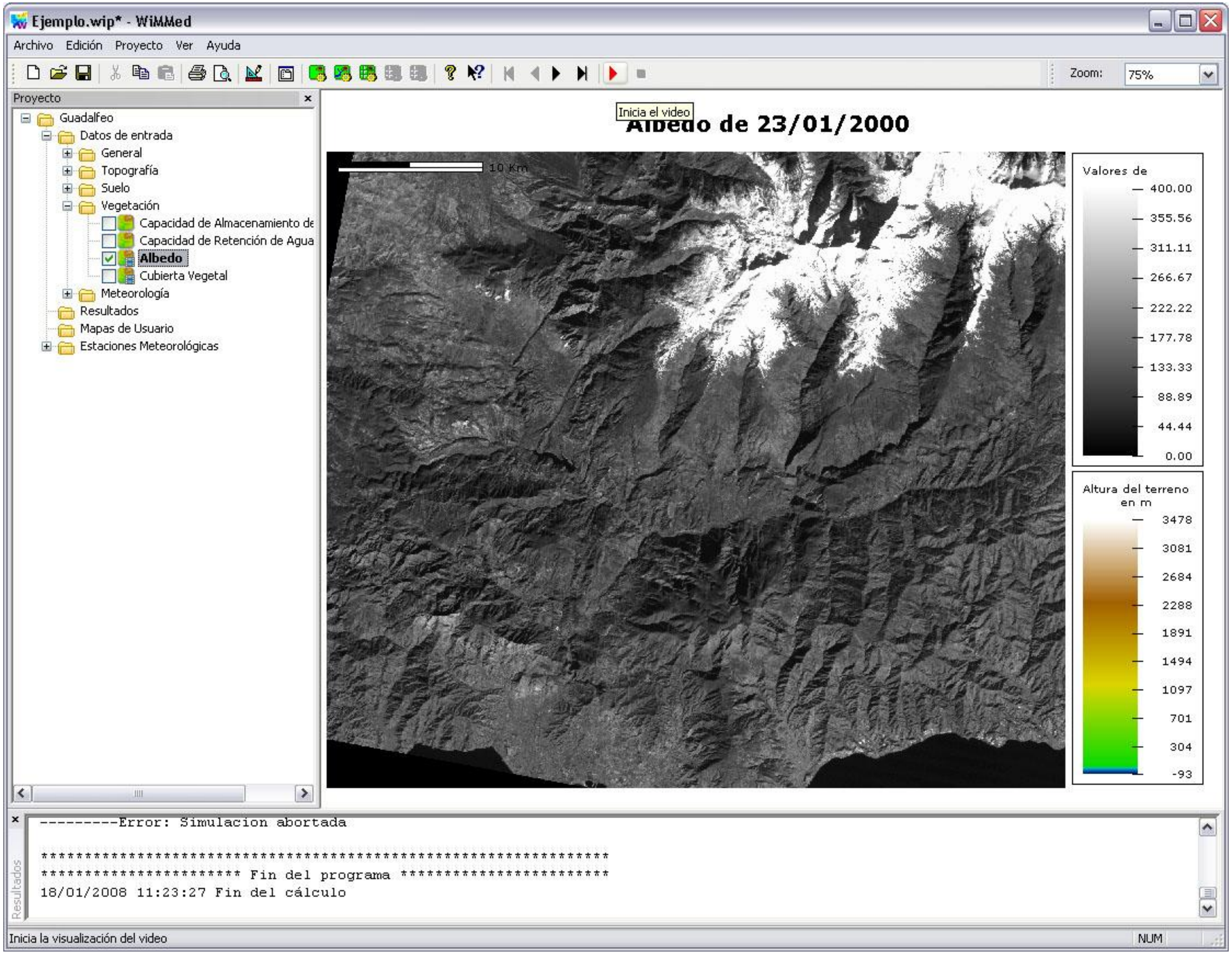
Hydrologic circulation

- Storms/dry periods (river channels)
- Hillslopes

Hydraulic circulation (river channels)

- 1D hydrodynamic equations
- Transient regimes
- Floodplains
- *Tidal contour conditions at the mouth*


Instalación de WiMMed 1.0
Selección de componentes
Seleccione qué características de WiMMed 1.0 desea instalar.
Marque los componentes que desee instalar y desmarque los componentes que no desee instalar. Presione Siguiente para continuar.
Seleccione los componentes a instalar:
Principal
Ejemplo
Descripción
Esta sección contiene el documento de ejemplo 'Cuenca del guadalfeo'.
Espacio requerido: 4.8MB
Powered by Bermasoft.com
< Atrás
Siguiente >
Cancelar



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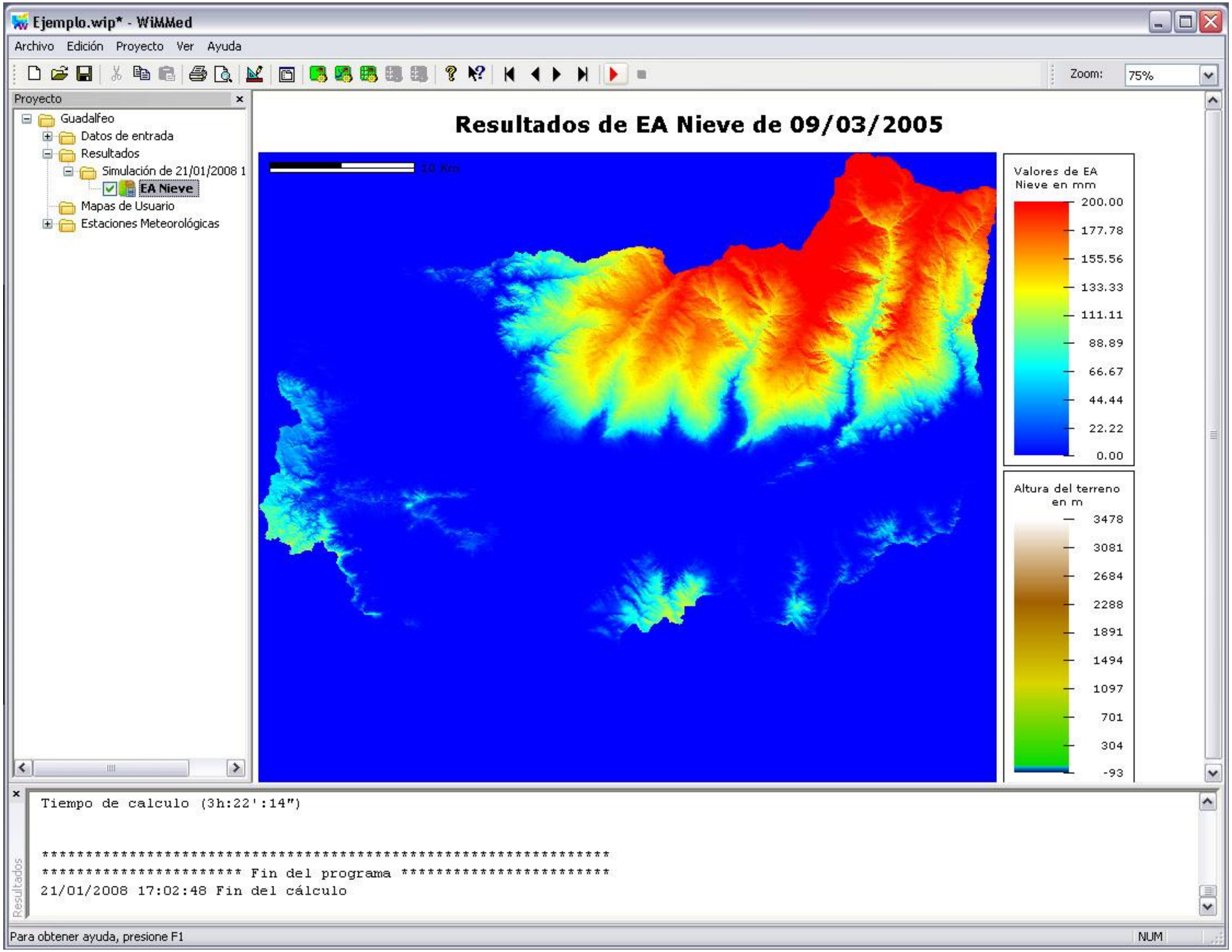
Propiedades de la capa
General
Opciones de visualización
Rango de valores
Automático
Calcula los valores máximo y mínimo a partir de los valores del mapa.
Personalizado
Mínimo
-885.171
Máximo
-335.33
Escala de color:
Azul - Blanco
Número de decimales:
2
Aceptar
Cancelar
Aplicar
Ayuda


Simulación Ciclo Superficial
Variables
Fechas
Regiones
Seleccionar por:
Fechas
Fecha inicial:
25/08/2006
Fecha final:
01/09/2006
septiembre de 2006
lun mar mié jue vie sáb dom
28 29 30 31 1 2 3
4 5 6 7 8 9 10
11 12 13 14 15 16 17
18 19 20 21 22 23 24
25 26 27 28 29 30 1
2 3 4 5 6 7 8
Hoy: 21/01/2008
Generar
Cancelar



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