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A hydrometeorological model ensemble strategy applied to four extreme rainfall events in a small-size basin of Majorca Island, Spain

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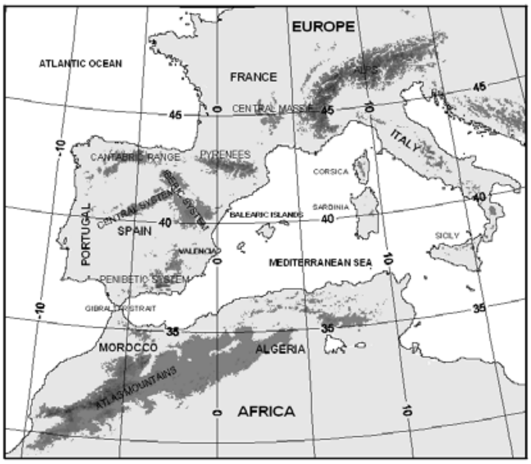
Introduction

- The region under study is located in Majorca, the biggest of the Balearic Islands, in the Mediterranean Spain
- The Albufera basin is the most important catchment in terms of size, water resources and socio economical activities (highlighted)
- It is formed by the Almedrà and Sant Miquel ephimeral rivers
- Whole extension of 610 km², heights close to 1500 m and maximum river length of 42 km



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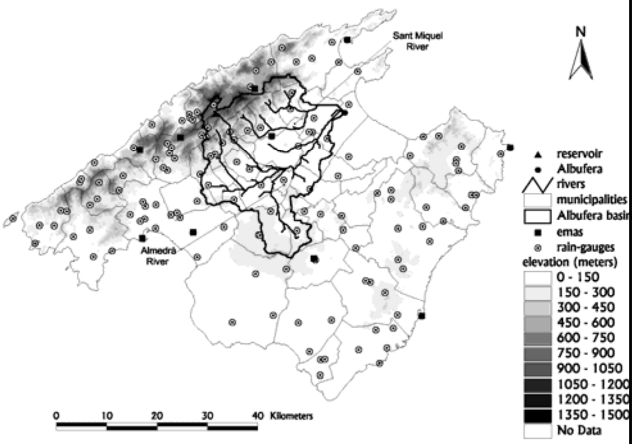
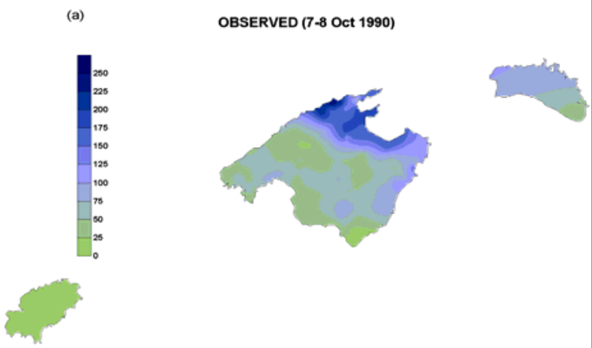


The intense precipitation events

- 7-8 October 1990: with accumulated values above 100 mm in 2 hours and total amounts over 240 mm
- 9-10 October 1990: with an hourly maximum close to 115 mm and cumulative values up to 235 mm
- 10-11 November 2001: with cumulative values of 240 mm in 24 hours and total amounts up to 400 mm
- 3-4 April 2002: with rainfall accumulations close to 230 mm in 24 hours and total values up to 300 mm



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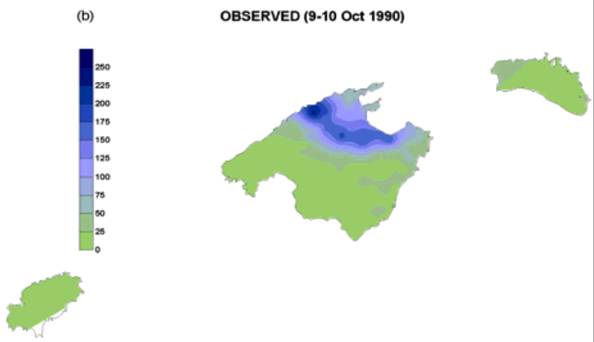

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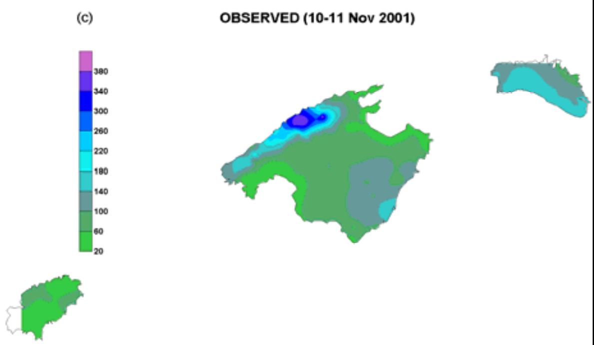

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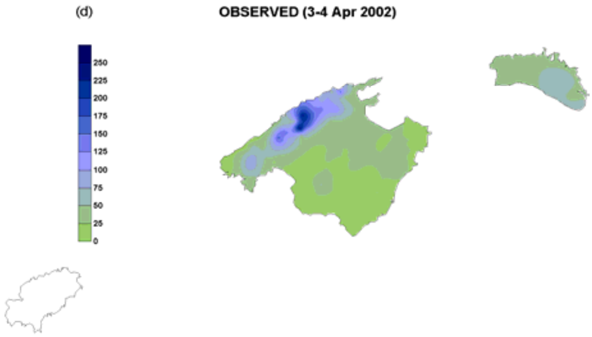


The episodes caused floods of different spatial and temporal scales in the Albufera basin

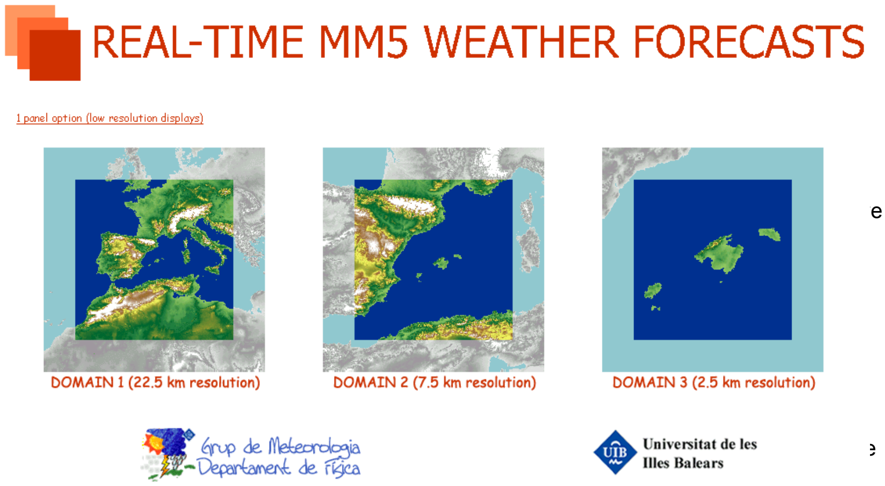
The rain-gauge network and input data

- Precipitation has been obtained from 24-h accumulated values of the Spanish Institute of Meteorology rain-gauges system for Majorca Island (100; 40 lie inside or near the basin)
- Precipitation is cumulated and recorded every 10 minutes in 12 automatic rain-gauges (emas) of the network
- To permit hydrological applications, the emas inside or close to the basin have been used to accumulate the 10-min series into 1-h and to build hourly series for the rest of the stations by means of:

$$p_{st_j}(t) = \frac{\sum_i \left(\frac{p_{emas_i}(t)}{d_{emas_i, st_j}} \cdot \frac{p_{Tst_j}}{p_{Temas_i}} \right)}{\sum_i \frac{1}{d_{emas_i, st_j}}}$$

where:
$p_{st_j}(t)$ is the 1-h value of the rainfall series at t for the daily j station;
$p_{emas_i}(t)$ is the 1-h value of the emas i at time-step t;
p_{Tst_j} is the daily accumulated value of the station j;
p_{Temas_i} is the daily accumulated value of the emas i
d_{emas_i,st_j} is the distance between the daily station j and the emas i

The hydro-meteorological chain



best estimation of the initial conditions for the hydrological parameters can be obtained from the high resolution observational campaign developed by the CORINE Land Cover project

• The experiments consider a 72-h period simulation

Multi-physics ensemble of MM5 simulations

Defined as multiple combinations of the model's physical parameterizations:

• to assess the sensitivity of the small-scale features of the QPFs to errors in the approximations of these schemes

• to better encompass the atmospheric processes leading to heavy precipitations

Explicit moisture scheme		Labels
IMPHYS=4	Simple ice	MM5-4-5
IMPHYS=5	Mixed-phase	MM5-5-5
IMPHYS=6	Graupel	MM5-6-5
IMPHYS=7	Reisner-Graupel	MM5-7-5 (control)
IMPHYS=8	Schultz	MM5-8-5

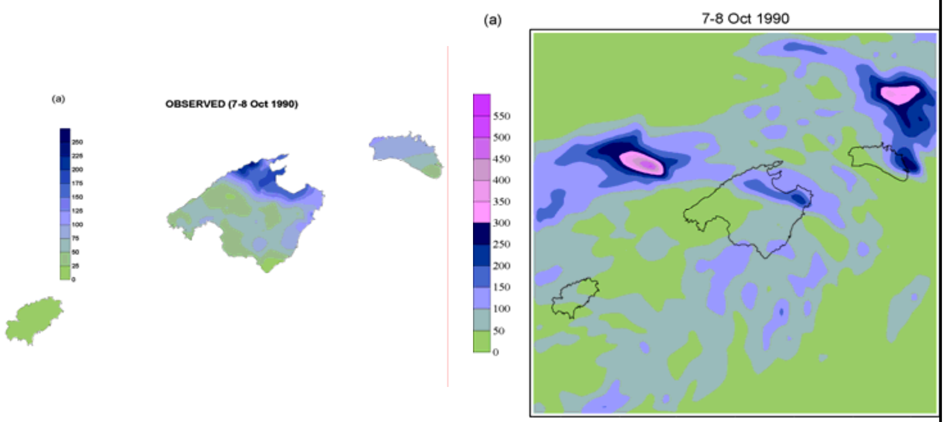
Convection scheme in 2nd domain

ICUPA=8	Kain-Fritsch	MM5-4-5-8, -5-5-8, -6-5-8, -7-5-8, -8-5-8

PBL parameterization

IBLTYP=5	Hong-Pan

Results: MM5 control simulations



Spatial distributions of accumulated rainfall patterns for the control simulations (in mm)

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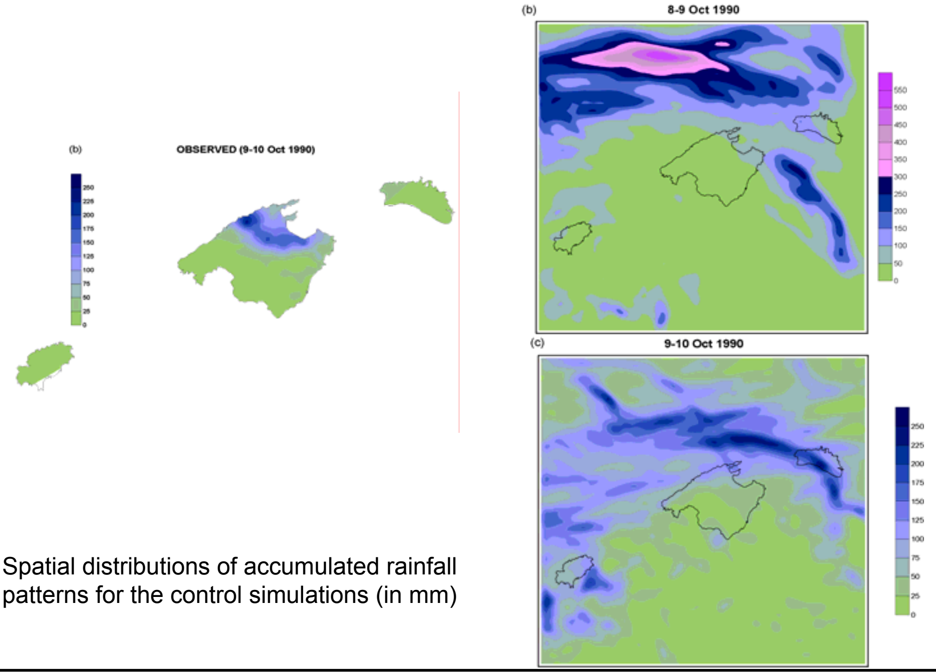

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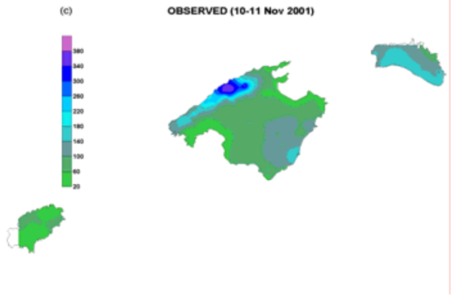

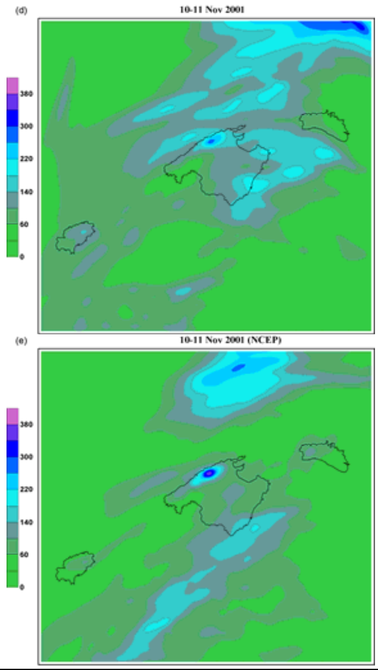

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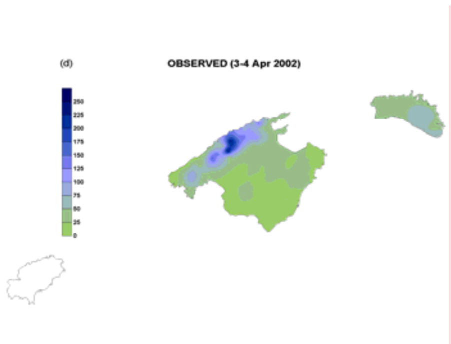
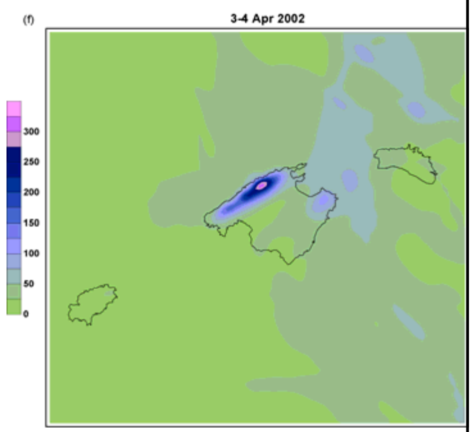




Spatial distributions of accumulated rainfall patterns for the control simulations (in mm)

Results: rain-gauge and MM5 control driven runoff simulations

It has been used to compare rain-gauge and QPFs driven discharge simulations:

- Nash-Sutcliffe efficiency criterion (NSE = 1: perfect simulation)

$$NSE = 1 - \frac{\sum_{i=1}^{n}(x_i - y_i)^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2};$$

$x_i = observed\ runoff$, $y_i = simulated\ runoff$,

$\bar{x} = mean\ observed\ runoff$

- % error in volume (% EV>0: volume simulated is overestimated)

$$\%\ EV = \left(\frac{V_S - V_O}{V_O}\right) \cdot 100$$

V_S = simulated hydrograph volume

V_O = observed hydrograph volume

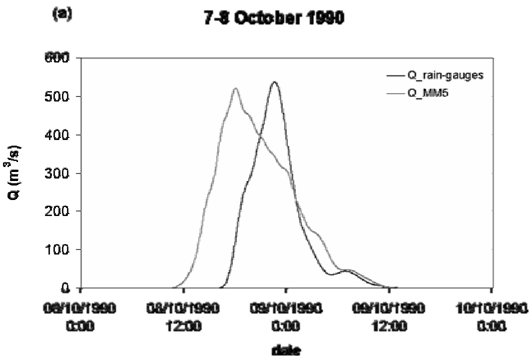
Results: rain-gauge and MM5 control driven runoff simulations

Maximum peak discharges for the 9-10 Oct 1990 flash-flood	Field estimation	Rain-gauge driven simulation
St. Miquel river	260 m^3/s (overflown)	356 m^3/s (+37%)
Almedrà river	366 m^3/s	346 m^3/s (-5.5%)

Rainfall-runoff model set-up reproduces in a satisfactory way the initial conditions of the basin for this case

Results: rain-gauge and MM5 control driven runoff simulations

MM5-control	NSE	% EV
7-8 Oct 1990	0.28	55.4
8-9 Oct 1990	-0.2	-98.7
9-10 Oct 1990	-0.15	-91.6
10-11 Nov 2001	-1.53	73.1
10-11 Nov 2001 (NCEP)	0.84	1.7
3-4 Apr 2002	0.60	27.8



- 7-8 Oct 1990, 10-11 Nov 2001 (NCEP) and 3-4 Apr 2002 experiments are found to be suitable in order to introduce discharge predictions
- 8-9, 9-10 Oct 1990 and 10-11 Nov 2001 runs show a very deficient performance. A noticeable impact due to the uncertainties of the initial and boundary conditions are found
- Can the multi-physical ensemble address the low forecast skill ?
- Explore the external-scale uncertainty of the QPFs owing to the physical parameterizations

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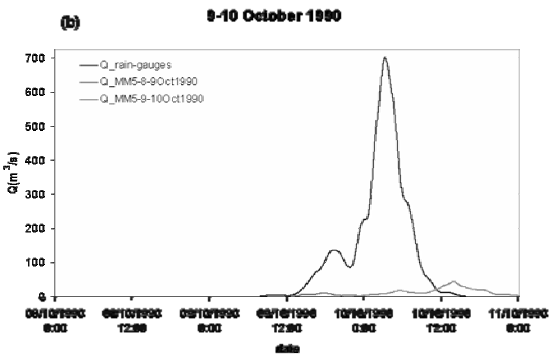

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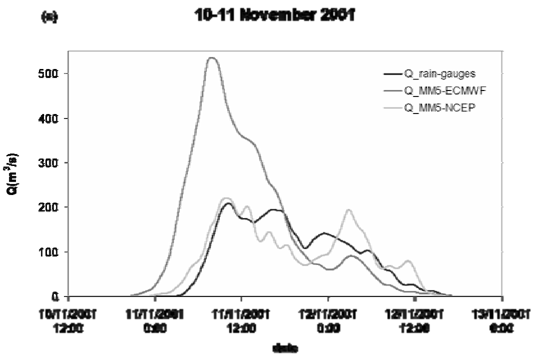

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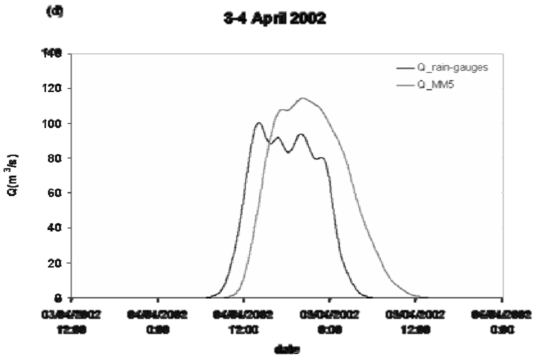

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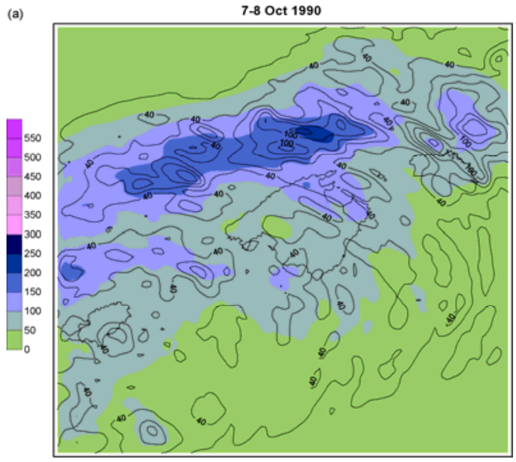
Results: multi-physics ensemble of MM5 simulations

Ensemble mean (mm; shaded contours) and ensemble standard deviation (mm; continuous line) of the accumulated precipitation for each case study



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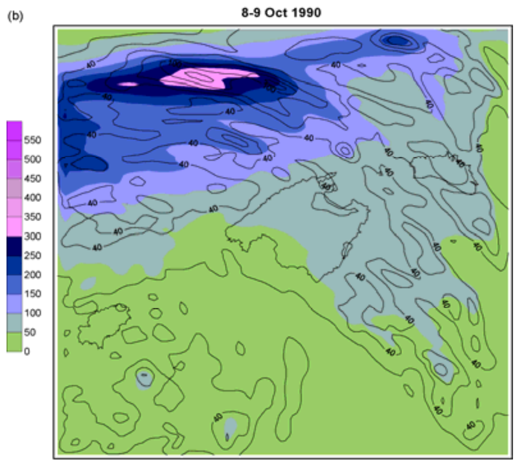

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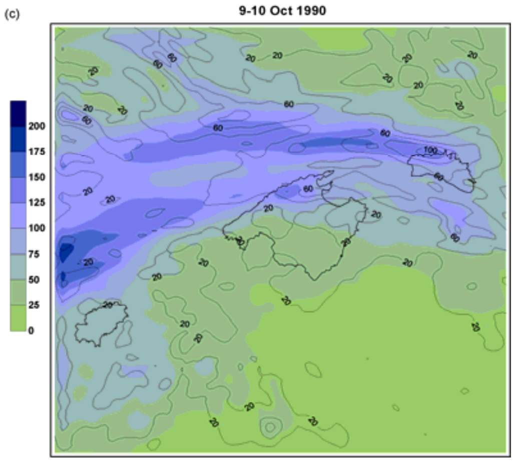

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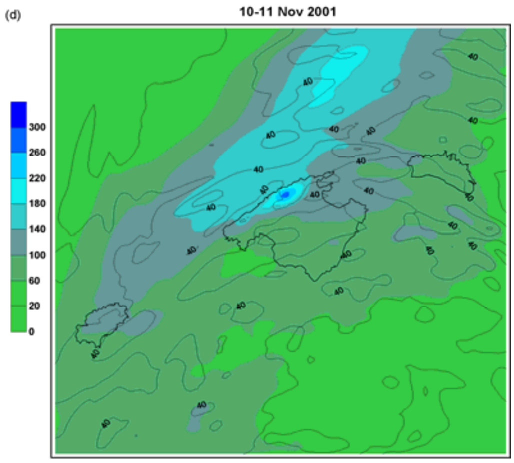

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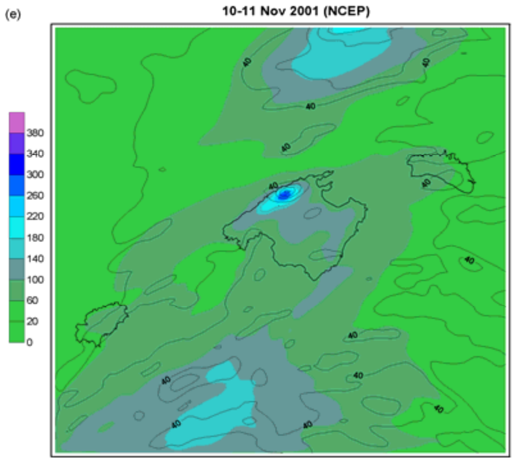

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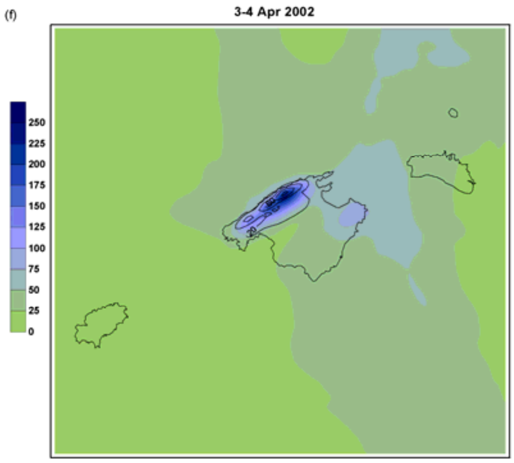

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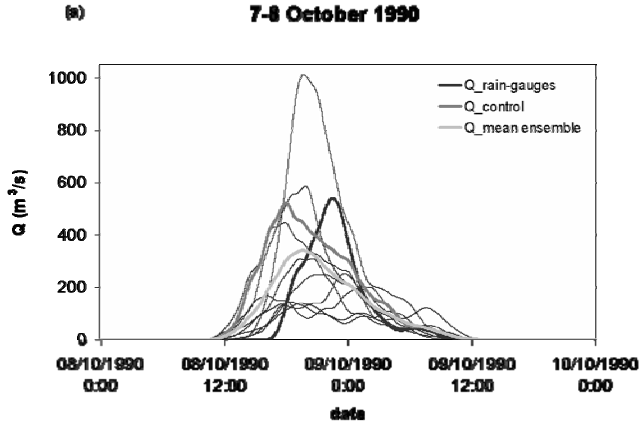

- Some members of the ensembles have outperformed the control simulations and have reduced biases at the basin outlet
- For the 10-11 Nov 2001 event, the MM5 ensemble driven by NCEP analyses have shown a better accuracy. But the differences owing to the initial and boundary conditions are considerable smoothed by the multi-physics ensemble
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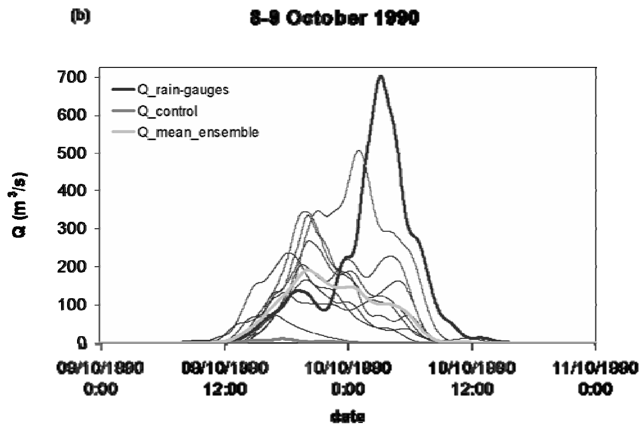

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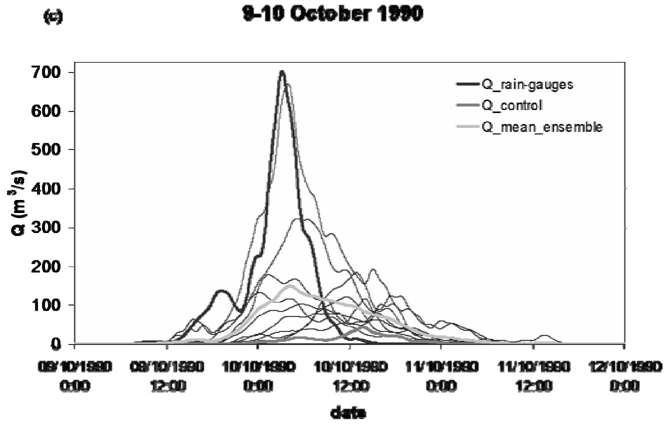

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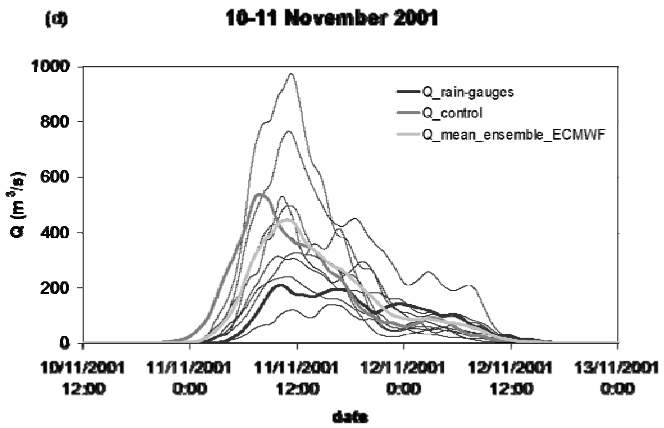

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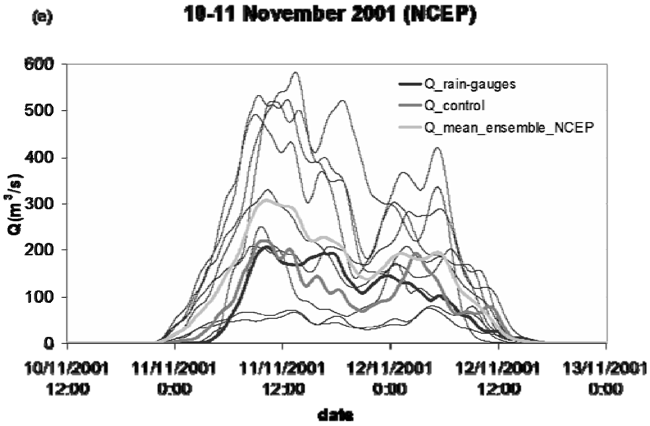

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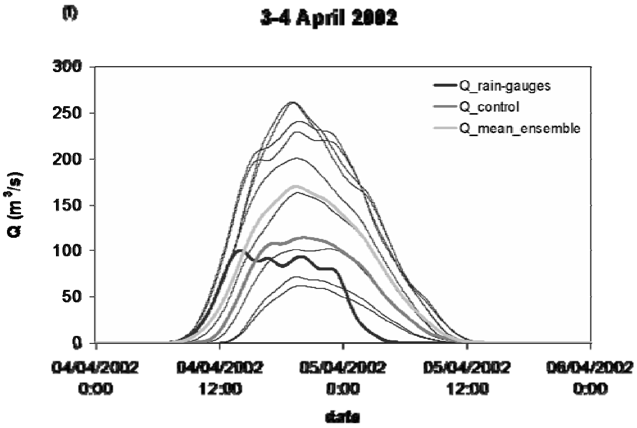

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	7-8 Oct 1990		*8-9 Oct 1990*		*9-10 Oct 1990*		*10-11 Nov 2001*		*10-11 Nov 2001 (NCEP)*		*3-4 Apr 2002*	
MM5-4-5	**0.75**	**-26.9**	0.22	-64.0	0.05	-70.2	0.49	41.0	**0.71**	58.8	-2.75	193.1
MM5-5-5	-0.73	118.7	0.06	-70.6	-0.08	-75.3	-5.29	190.5	0.51	147.5	-0.89	129.3
MM5-6-5	0.31	-51.4	-0.02	-56.0	-0.14	-65.1	0.03	59.0	0.52	135.1	-2.82	187.4
MM5-7-5 (control)	0.28	55.4	-0.2	-98.7	-0.15	-91.6	-1.53	73.1	**0.84**	**1.7**	**0.60**	**27.8**
MM5-8-5	0.31	36.5	-0.17	-88.9	-0.13	-60.0	-0.46	43.8	**0.74**	**-15.8**	0.50	-42.4
MM5-4-5-8	0.36	-56.0	0.28	-35.8	0.17	-60.5	**0.57**	**18.5**	-1.44	-56.1	-2.38	183.0
MM5-5-5-8	**0.63**	**-19.2**	**0.61**	**-4.7**	0.28	-62.7	-0.55	48.2	-1.28	-56.3	-0.02	78.8
MM5-6-5-8	0.38	-26.9	**0.53**	-43.3	**0.56**	**-5.2**	**0.71**	**-15.4**	**0.63**	71.83	-2.88	188.8
MM5-7-5-8	**0.58**	**-19.8**	0.26	-47.8	0.34	-36.5	**0.62**	-51.8	0.48	169.0	**0.57**	**13.5**
MM5-8-5-8	0.21	46.9	0.1	-47.9	**0.69**	50.4	-7.61	172.6	0.52	142.0	**0.55**	**-32.5**
mean	**0.68**	**5.7**	**0.26**	**-55.8**	**0.3**	**-47.7**	**-0.23**	**57.9**	**0.78**	**59.8**	**-0.14**	**92.7**

Conclusions and further remarks

• The high-resolution numerical weather control forecasts have reproduced some of the extreme precipitation events under study: feasibility to introduce discharge predictions despite the small-sized basin

• Some elements of the multi-physics ensemble outperform the control simulations and reduce biases at the Albufera outlet. The inclusion of an enhanced description for convection seems to benefit some episodes (e.g. 9-10 Oct 1990 convectively driven flash-flood)

• Initial and boundary conditions uncertainties are found to play an important role in the quality of the control QPFs for the 10-11 Nov 2001 event. These errors are smoothed by the use of the multi-physics ensemble

• The one-way coupling between the meteorological and hydrological models has been regarded as a complementary tool to evaluate the QPFs

• No precipitation assimilation technique has been used in the one-way coupling: future implementation of applications such as statistical downscaling or disaggregation techniques