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Hydro-meteorological model simulations of extreme precipitation events in a small-size basin of Mallorca, Balearic Islands

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Purpose

Hydro-meteorological model simulations of several extreme precipitation events are proposed in order to assess the feasibility of discharge predictions driven by numerical weather forecasts for a small-size basin of Mallorca. The study is performed for four intense precipitation events, which caused flood events of different magnitude over the Albufera river basin. HEC-HMS hydrological model was used to generate the runoff simulations. The MM5 non-hydrostatic numerical mesoscale model was used to provide quantitative precipitation forecasts (QPFs) for the events. The MM5 runoff driven simulations are compared with stream-flow simulations driven by rainfall observations. In addition to the control MM5 simulation, a multi-physics ensemble is carried out in order to evaluate the reliability of the discharge forecast resulting by the one-way coupling between meteorological and hydrological models. That is, different combinations of the physical parameterizations of the MM5 model (explicit microphysical and moist convection and boundary layer schemes) have been adopted, trying to improve the description of the phenomena determining the precipitation amount.

Introduction

Case study area

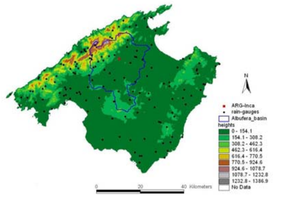

Figure 1. It is highlighted the Albufera basin together with the 10-min (in red) and the 24-h accumulated precipitation (in black) rain-gauges

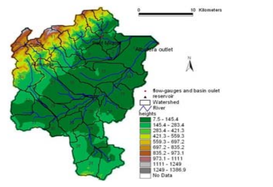

Figure 2. The basin has a whole extension of 610 km^2 with heights near 1100 m and a maximum length of 42 km. It is shown the main watercourses, tributaries and the sub-watershed numeration. DTM of the Albufera basin has a resolution of 50 m

The region under study is located in Mallorca, the biggest of the Balearic Islands, in the Mediterranean Spain. The Albufera river basin is of major importance, since it forms the biggest catchment of the island -covering an important area of cropping- and it ends in the main wet land of Mallorca, s'Albufera natural park (1688 Ha).

The intense precipitation episodes

- **Cases 1 and 2:** precipitation took place on **7th-9th Oct 1990** with accumulated rainfall values close to 240 mm in 24 h and total amounts up to 400 mm.
  Case 1: **7th -8th Oct** with cumulative values over 240 mm
  Case 2: **9th Oct** with cumulative values up to 235 mm
- **Case 3:** precipitation took place on **10th-12th Nov 2001** with accumulated rainfall of 240 mm in 24 h and total amounts close to 400 mm
- **Case 4:** precipitation took place on **3th-5th Apr 2002** with accumulated rainfall values close to 230 mm in 48 h and total amounts up to 300 mm

Precipitation has been obtained from 24-h accumulated values of the National Meteorology Institute (INM) rain-gauges system (~ 140). Precipitation is cumulated and recorded every 10 minutes in 12 automatic rain-gauges (EMAS) of the network. The EMAS located inside or very close to the Albufera basin and with the whole rainfall series for the events, have been used to build 10-min series for the rest of the network.

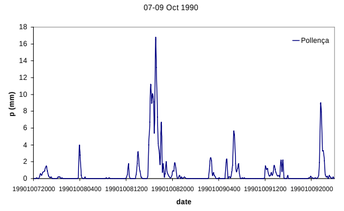

Figure 3. 10-min accumulated rainfall at one of the automatic rain-gauges of the network for the Oct 1990 episode

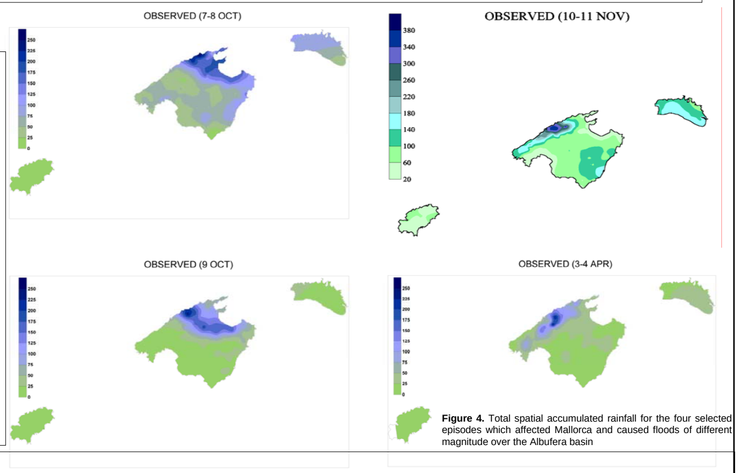

Figure 4. Total spatial accumulated rainfall for the four selected episodes which affected Mallorca and caused floods of different magnitude over the Albufera basin

The hydro-meteorological chain

The HEC-HMS and MM5 models set-up

HEC-HMS is a physically based model. A semi-distributed and event-based configuration is used. The loss rate is calculated using the Soil Conservation Service Curve Number (SCS-CN). A synthetic unit hydrograph (UH) model provided by SCS is used to convert precipitation excess into direct runoff. The flood hydrograph is routed using the Muskingum method.
The lack of flow measurements in the basin poses great difficulties to the evaluation of the rain-gauge driven runoff simulations. Therefore, it has not been possible to carry out a calibration and a verification task for the hydrological model. The model has been run under the assumption that a best estimation of the hydrological model parameters can be obtained from the high resolution campaign developed by the CORINE project.

MM5 is configured as in the real-time operational version at UIB (http://mm5forecasts.uib.es). Simulations are designed using 24 vertical sigma-levels and 3 spatial domains with 121x121 grid points. The respective horizontal resolutions are 22.5, 7.5 and 2.5 km centred in the Balearic Islands. The interaction between the domains follows a two way nesting strategy. To initialize and to provide the boundary conditions, ECMWF analysis are used -an additional experiment for the Nov 2001 event using NCEP analysis is also included - and these are improved with surface and upper-air observations. To parameterise moist convection effects, the Kain-Fristch scheme is used in the large domain and convection is explicitly resolved in the intermediate and inner domains. Since it is debatable whether a 7.5 km resolution domain can resolve convection appropriately without a convection scheme, a set of additional experiments with parameterized convection in the second domain has been designed to explore this issue.

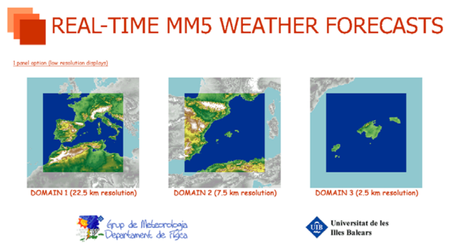

Figure 5. Operational configuration of the MM5 model. Based on previous research, the MRF boundary layer parameterization scheme (option 5 in MM5 model) was selected. Then, the **multi-physics ensemble** is defined as several combinations of the explicit moisture schemes (options 4, 5, 6, 7 and 8 in the model) and the inclusion, or absence, of the Kain-Frisch convection scheme (option 8 in the MM5 model) in the second domain:
Microphysics schemes + Kain-Fritsch convection scheme only in first domain: Simple Ice (MM5-4-5), Mixed-phase (MM5-5-5), Graupel (MM5-6-5), Reisner-Graupel (MM5-7-5; **control**), and Schultz (MM5-8-5)
Microphysics schems + Kain-Fritsch convection scheme also in second domain. Labelled as: MM5-4-5-8, -5-5-8, -6-5-8, -7-5-8 and -8-5-8 respectively

Results

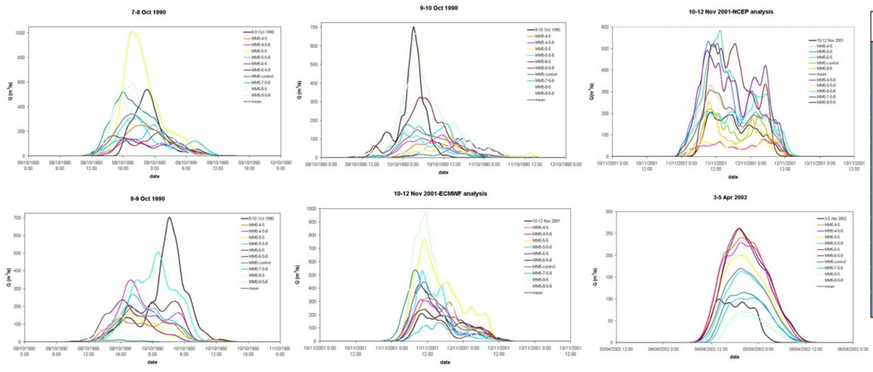

Figure 6. Rain-gauges and MM5 multi-physics driven runoff simulation ensemble

	7-8 Oct 1990		8-9 Oct 1990		9-10 Oct 1990		10-12 Nov 2001		10-12 Nov 2001 (NCEP)		3-5 Apr 2002	
MM5-4-5	**0.75**	**36.7**	0.22	178.1	0.05	236	0.49	-29.1	**0.71**	**-37.0**	-2.88	-98.3
MM5-5-5	-0.73	-54.3	0.06	240.3	-0.08	304.8	-5.29	-65.6	**0.51**	**-59.5**	-0.97	-56.9
MM5-6-5	0.31	105.7	-0.02	127.3	-0.14	106.4	0.03	-37.1	**0.52**	**-57.5**	-2.95	-65.6
MM5-control	0.28	-35.6	-0.2	7536.5	-0.15	1090.9	-1.53	-42.2	**0.84**	**-1.7**	**0.58**	**-22.7**
MM5-8-5	0.31	-26.7	+0.17	800.2	-0.13	149.83	+0.46	-30.3	**0.74**	**18.8**	0.5	71.4
MM5-4-5-8	0.36	127	0.28	55.7	0.17	153.2	**0.57**	**-15.6**	-1.44	127.8	-2.5	-65.1
MM5-5-5-8	**0.63**	**23.8**	**0.61**	**62**	0.28	168.2	-0.55	-32.5	-1.28	128.9	-0.07	-44.7
MM5-6-5-8	0.38	36.7	**0.53**	**76.3**	**0.66**	**5.52**	**0.71**	**18.1**	**0.63**	**-41.8**	-3.02	-65.8
MM5-7-5-8	**0.68**	**24.8**	0.26	91.5	0.34	57.5	**0.62**	**107.9**	0.48	-62.9	**0.55**	**-12.9**
MM5-8-5-8	0.21	-31.9	0.1	91.9	**0.69**	**-33.5**	-7.61	-83	**0.52**	**-68.7**	**0.55**	**46.5**
mean	**0.68**	**-6.4**	**0.26**	**126.1**	**0.30**	**91.1**	**-0.18**	**-36.6**	**0.79**	**-37.4**	**-0.2**	**-48.7**

Table 1. Statistical indices for the ensemble of MM5 simulations and for the episodes under study (left column: Nash-Sutcliffe criterion, right column: % error in volume)

Conclusions

- The high-resolution (2.5 km) numerical weather forecast (MM5-control) in this complex orography area reproduces accurately some of the extreme precipitation events under study, allowing the issue of valuable discharge predictions despite the small size of the basin.
- An ensemble of microphysical, moist convection and boundary layer parameterizations in the MM5 simulations has been adopted in order to address the low forecasting skill of the hydro-meteorological chain in some episodes. Thus, some members of the ensemble outperform the control simulation and reduce biases at the Albufera outlet, where the control simulation would have not produced enough accurate runoff forecasts.
- A multi-analysis ensemble (NCEP and ECMWF experiments for the Nov 2001 event) was also introduced to address the hydro-meteorological chain errors owing to initial and boundary conditions in the databases.
- The one-way coupling of the MM5 and the HEC-HMS models can be regarded as a complementary tool to evaluate QPFs for the verification of meteorological model performance.

References

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Acknowledgements

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