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WATER RESOURCES
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Analysis of a short-duration severe precipitation event in a small ungauged basin through a semi-distributed hydrological model

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A passing cyclone over Western Crete in October 17, 2006 caused a heavy precipitation event which produced a flash flood in a small agricultural basin.

In this work we model the particular short-lived and high-intensity precipitation event over the studied basin, by using the semi-distributed hydrological model HBV-light. The calibration was implemented with post-flood field data from witnesses that indicated the time to peak flow and the maximum water depth of the passing flood wave. Parameter sensitivity analysis was performed, following the one parameter at a time approach.

The parameters concerning the soil moisture and response routine affected mostly the magnitude of the peak hydrograph, whereas the routing routine parameter had a great effect on the time of peak discharge. The criterion of model verification was the best performance of the Nash-Sutcliffe efficiency index.

Case Study – Post-flood field data



17/10/2006 ALMYRIDA FLASH FLOOD, Crete, Greece

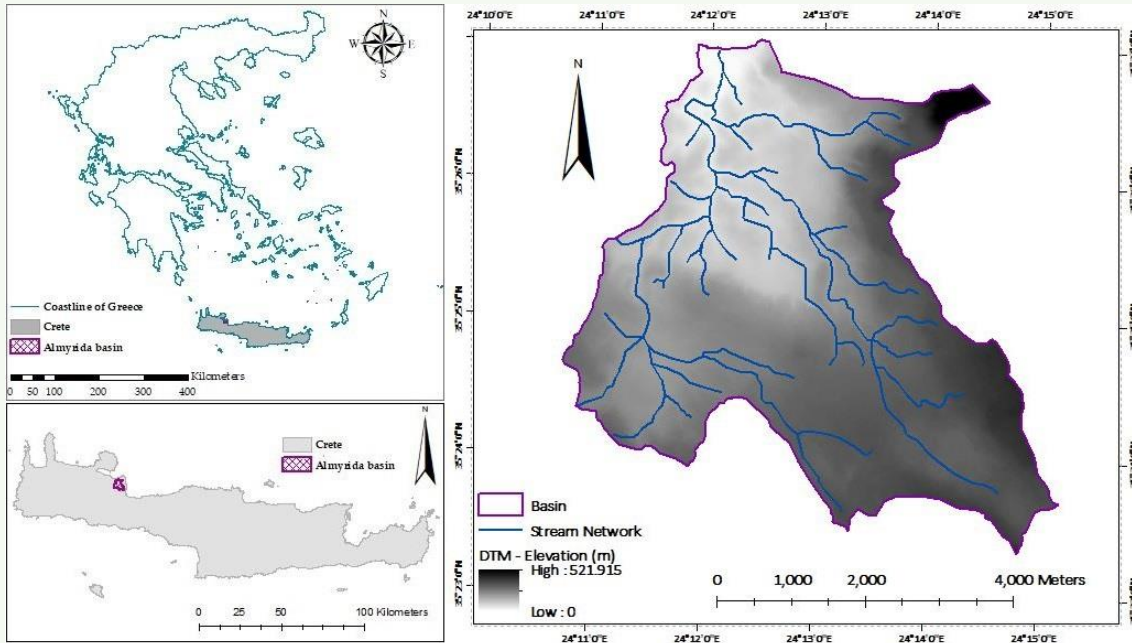


Photo source:
http://www.hydrate.tesaf.unipd.it/warehouse/europeandatacenter/Greece/Attached_Documents/Almyrida_2006/Photos_Almyrida_2006.pdf

Rain gage records:

- max hourly: 45 mm
- 4hours: 117 mm
- daily: 196.2 mm



Measured depth on
control wall → 2m

Time of passage
→ 12:00

HBV-light model, Methodology (1)



- *Conceptual model for runoff simulation*
- *Semi-distributed model, allowing the division of the basin into elevation and vegetation zones*
- *Can be applied for event-based modeling, as the studied one*
- *Uses a **warming-up period** so that the initial state values progress to their proper values based on the meteorological data and parameter calibration*
- *Precipitation, temperature and evaporation data are used as input*
- *The model works with discharge in millimeters rather than discharge volumes¹*

	Routine	Input	Parameters	Output
Distributed	Snow Routine	Precipitation, Temperature	<i>TT</i> (oC), <i>CFMAX</i> (mm/15min oC), <i>SP</i> , <i>SFCF</i> , <i>CFR</i> , <i>CWH</i>	Snow-pack, snowmelt ^a
	Soil Moisture Routine	Potential evaporation (PET), Precipitation, Snowmelt	<i>FC</i> (mm), <i>LP</i> , <i>BETA</i>	Actual evaporation (AET), soil moisture, groundwater recharge
Lumped	Response Routine	Groundwater recharge, PET	<i>PERC</i> (mm/15min), <i>UZL</i> (mm), <i>K0</i> , <i>K1</i> , <i>K2</i> (1/15min)	Runoff to stream, groundwater level
	Routing Routine	Runoff to stream	<i>MAXBAS</i> (n*15min)	Runoff at outlet

^a *Temperatures are higher than the threshold temperature, thus the precipitated water is exclusively rain*

¹Seibert, J. *HBV light version 2 User's Manual*, 2005. Available online: https://www.geo.uzh.ch/dam/jcr:c8afa73c-ac90-478e-a8c7-929eed7b1b62/HBV_manual_2005.pdf (accessed on 20 November 2020)

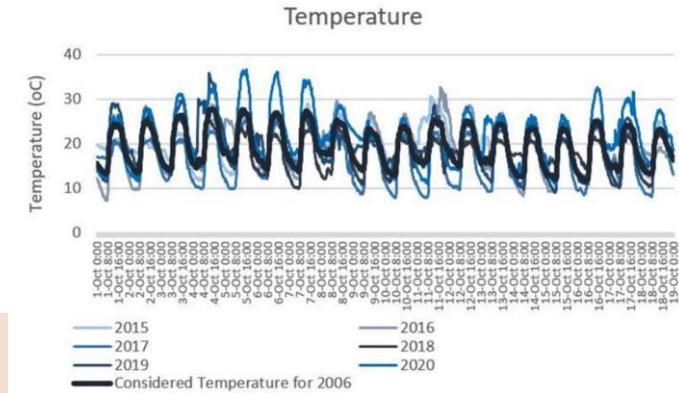
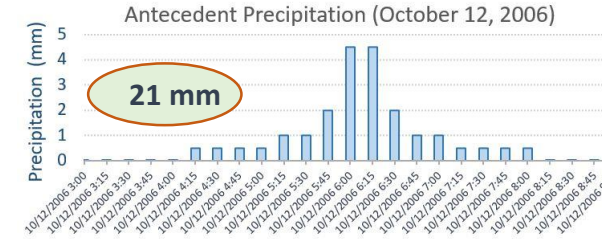
HBV-light model, Methodology (2)



Warm-up period: 1-16 October 2006 (21mm on October 12th)

Simulation period: 17-18 October 2006 (196.2mm)

- *Precipitation data* on a 15-minutes time-step
- Non-available temperature data for October 2006 → *Temperature data* taken as an **average** of six years' corresponding period records (2015~2020)
- *Potential evaporation (ET)* estimations through the Blaney-Criddle method¹
- *Discharge data* through the **validated hydrograph** via the HEC-HMS model²



Land Uses in six elevation zones	% Vegetation zone 1	% Vegetation zone 2	% Vegetation zone 3
Natural meadows (143m)		1.57	
Olive trees (157m)	40.56		
Complex arable land areas (220m)	10.94		
Sclerophyllous vegetation (233m)			26.07
Pastures (234m)		4.52	
Predominantly agricultural areas with significant areas of natural vegetation (246m)	16.34	Soil Moisture Routine	

Potential evaporation
(mm/15minutes):

$$ET = k \times p \frac{(1.8T + 32)}{3.94} \times \frac{15}{31 \times 24 \times 60}$$

k=0.7 (crop coefficient)³

p=7.87 (October's percentage of total daytime hours out of total daytime hours of the year (365x12))

¹Blaney, H.F.; Criddle, W.D. Determining Water Requirements in Irrigated Area from Climatological Irrigation Data; US Department of Agriculture, Soil Conservation Service, Tech. Pap. No. 96, 48 pp., 1950.

²Sarchani, S.; Tsanis, I. Analysis of a Flash Flood in a Small Basin in Crete. Water 2019, 11, 2253. doi:10.3390/w11112253.

³Allen, R.G.; Pereira, L.S.; Raes, D.; Smith, M. Crop Evapotranspiration -Guidelines for computing crop water requirements; FAO Irrigation and Drainage Paper No.56, 1998.

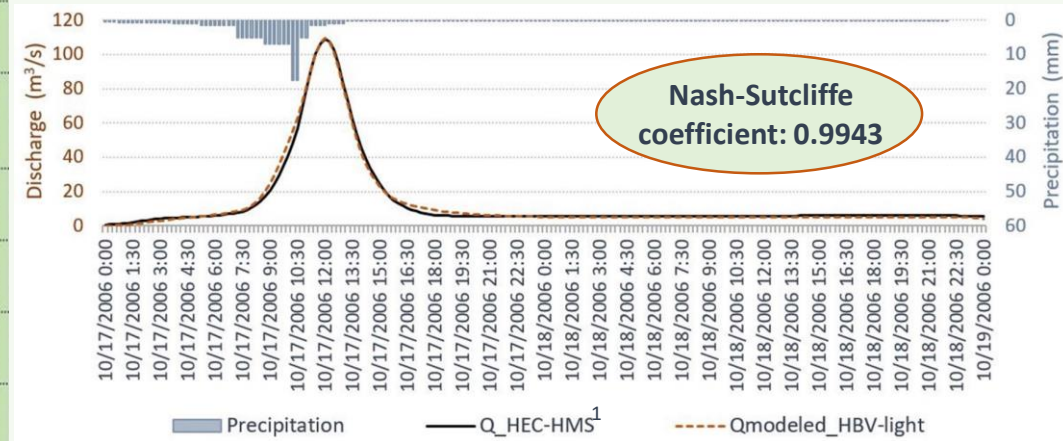
Results: Parameter sensitivity analysis – Verified hydrograph



Test Number	SOIL MOISTURE									RESPONSE					ROUTING	Qmax modeled (m³/s)	Qmax observed (m³/s)	Simulated Peak Time compared to Observed (min)	Model Efficiency
	Vegetation zone 1			Vegetation zone 2			Vegetation zone 3			PERC (mm/15min)	UZL (mm)	K0 (1/15min)	K1 (1/15min)	K2 (1/15min)	MAXBAS (n*15min)				
	FC (mm)	LP	BETA	FC (mm)	LP	BETA	FC (mm)	LP	BETA										
1	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	109.4		0	0.9943
2	1	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	187.3		0	0.0697
3	50	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	180.5		0	0.3989
4	100	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	159.2		0	0.9499
5	200	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	130.5		0	0.9491
6	445	0	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	48.0		0	0.5582
7	445	0.3	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	69.2		0	0.8029
8	445	1	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	169.6		0	0.4348
9	445	0.615	1	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	134.4		0	0.8784
10	445	0.615	3	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	98		0	0.9815
11	445	0.615	5	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	80.3		0	0.8882
12	445	0.615	2.15	1	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	109.9		0	0.9918
13	445	0.615	2.15	200	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	107.1		0	0.9947
14	445	0.615	2.15	65	0	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	108.2		0	0.9962
15	445	0.615	2.15	65	0.5	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	108.9		0	0.9955
16	445	0.615	2.15	65	0.88	1	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	108.4		0	0.9942
17	445	0.615	2.15	65	0.88	5	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	109.6		0	0.9939
18	445	0.615	2.15	65	0.88	3.05	1	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	137.4		0	0.8617
19	445	0.615	2.15	65	0.88	3.05	100	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	127.4		0	0.9594
20	445	0.615	2.15	65	0.88	3.05	200	0.66	2.05	0.05	7	0.125	0.0985	0.0495	12	117.2		0	0.9887
21	445	0.615	2.15	65	0.88	3.05	455	0	2.05	0.05	7	0.125	0.0985	0.0495	12	82.6		0	0.9133
22	445	0.615	2.15	65	0.88	3.05	455	0.3	2.05	0.05	7	0.125	0.0985	0.0495	12	91.2		0	0.9583
23	445	0.615	2.15	65	0.88	3.05	455	1	2.05	0.05	7	0.005	0.0985	0.0495	12	130.7		0	0.9155
24	445	0.615	2.15	65	0.88	3.05	455	0.66	1	0.05	7	0.125	0.0985	0.0495	12	118.1		0	0.9759
25	445	0.615	2.15	65	0.88	3.05	455	0.66	3	0.05	7	0.125	0.0985	0.0495	12	104.6		0	0.994
26	445	0.615	2.15	65	0.88	3.05	455	0.66	5	0.05	7	0.125	0.0985	0.0495	12	98.2		0	0.9822
27	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	1	7	0.125	0.0985	0.0495	12	99.5		0	0.9648
28	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	3	7	0.125	0.0985	0.0495	12	69.8		(1*15)	0.7545
29	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	5	7	0.125	0.0985	0.0495	12	59.3		(2*15)	0.6632
30	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	10	7	0.125	0.0985	0.0495	12	56.8		(3*15)	0.6252
31	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	0	0.125	0.0985	0.0495	12	109.9		0	0.986
32	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	15	0.125	0.0985	0.0495	12	105.8		0	0.9872
33	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	40	0.125	0.0985	0.0495	12	82		(1*15)	0.8913
34	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0	0.0985	0.0495	12	82		(1*15)	0.8913
35	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.25	0.0985	0.0495	12	119.6		(-1*15)	0.9539
36	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.99	0.0985	0.0495	12	131.3		(-2*15)	0.7799
37	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0	0.0495	12	90.2		(1*15)	0.9405
38	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.2	0.0495	12	118.1		0	0.9634
39	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.99	0.0495	12	131.2		(-2*15)	0.7316
40	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.001	12	108.3		0	0.9918
41	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.01	12	108.7		0	0.9942
42	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.1	12	109.5		0	0.9941
43	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	4	136.4		(-4*15)	0.6433
44	445	0.615	2.15	65	0.88	3.05	455	0.66	2.05	0.05	7	0.125	0.0985	0.0495	16	100		(2*15)	0.9545

One Parameter at a time approach

- The maximum water content of the soil box (FC) was expected to be greater in the crops and forest areas than in the pastures/meadows
- The threshold value for AET reaching PET (LP) was considered small in crop zones, where AET was high



¹Sarchani, S.; Tsanis, I. Analysis of a Flash Flood in a Small Basin in Crete. Water 2019, 11, 2253. doi:10.3390/w11112253

- *The most significant parameters affecting the magnitude of the peak hydrograph were the max water content of the soil box (FC), the threshold value for AET reaching PET (LP), the percolation rate (PERC), and the recession coefficients K0 and K1*
 - *Raising the FC and PERC parameters, while lowering the LP parameter resulted to decreased maximum runoff*
 - *Raising the K0 and K1 recession parameters resulted to increased maximum runoff*
- *The parameter affecting substantially the time of occurrence of peak flow was the MAXBAS runoff transformation parameter - The K0 and K1 coefficients affected also significantly the time of peak flow*
 - *The MAXBAS rise resulted to a shift of the peak runoff time forward, along with a decrease in the runoff*
- *The recession was more considerable in the upper groundwater box than in the intermediate and lower one ($K0 > K1 > K2$)*