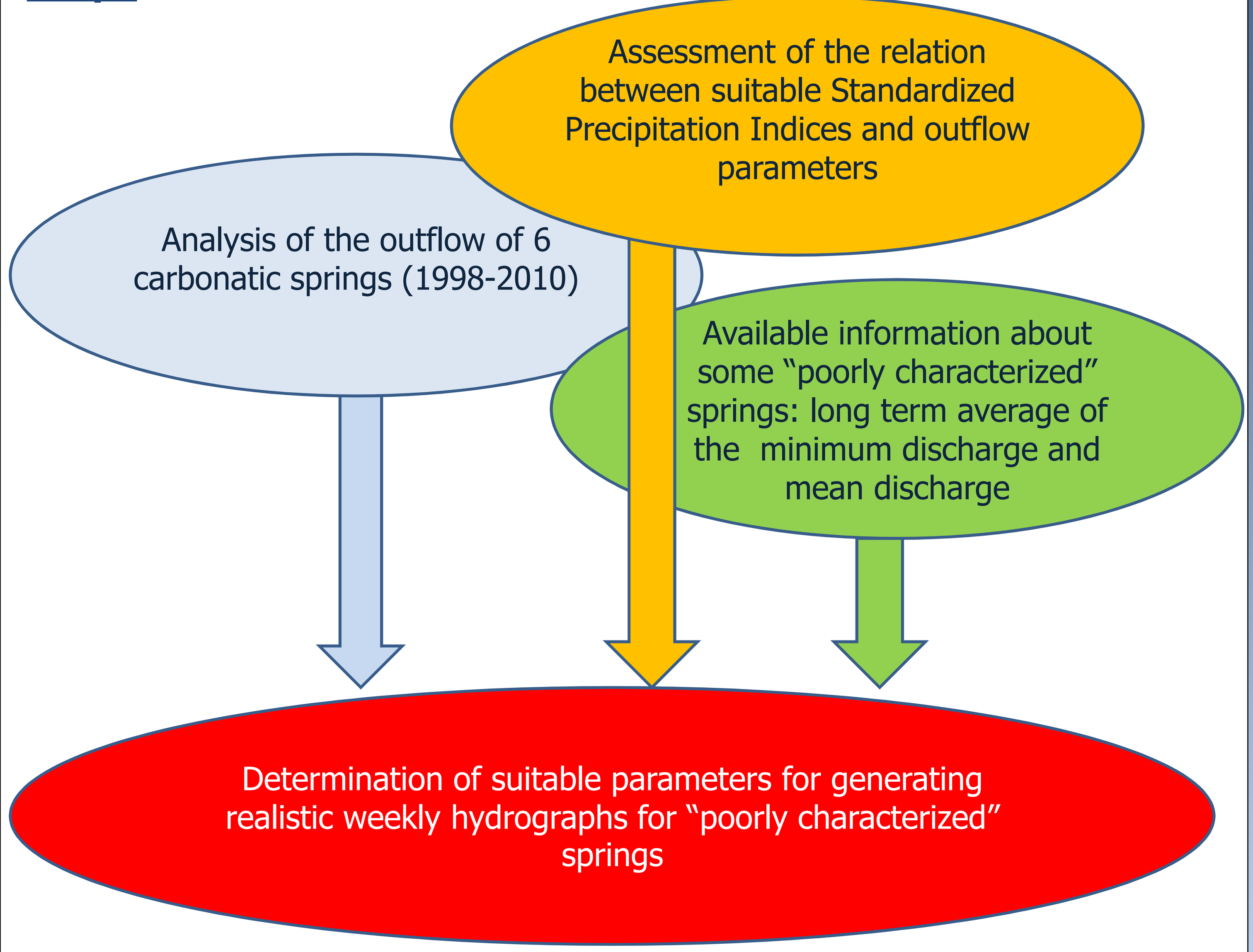
MODELING KARST SPRING DISCHARGE IN RELATION TO STANDARDIZED PRECIPITATION INDICES
A NEW METHOD FOR FORECASTING WATER SCARCITY CONDITIONS.

Emanuele Romano*, Andrea Del Bon, Anna Bruna Petrangeli, Elisabetta Preziosi
IRSA-CNR – Water Research Institute – National Research Council of Italy *Corresponding author. Email: romano@irsa.cnr.it

Scope



Study area and available data

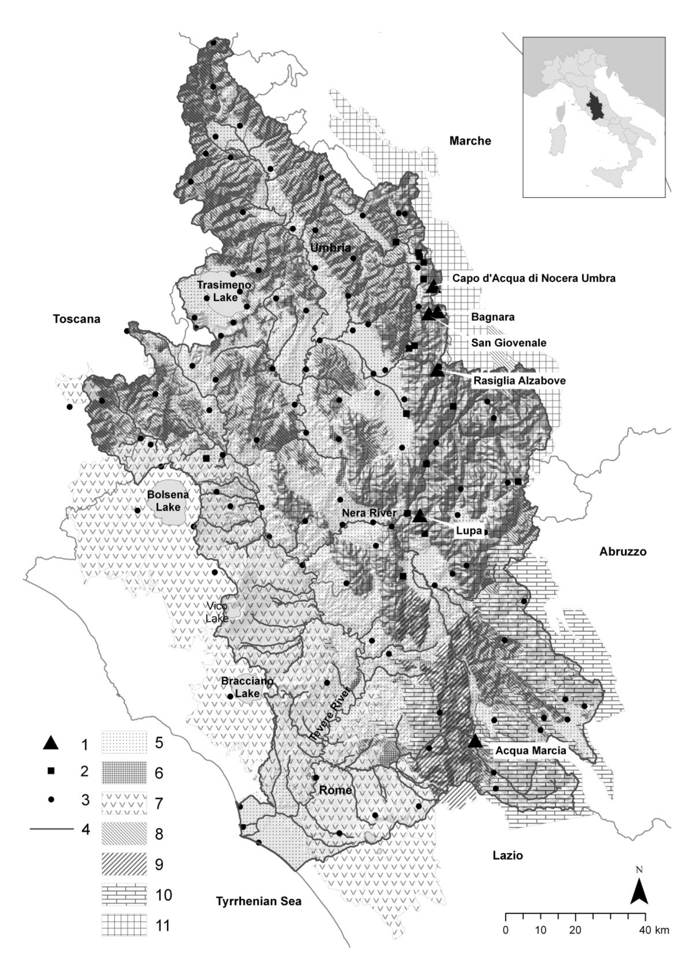


Fig. 1 - Tiber river basin. 1: studied springs, 2: other springs; 3: rain gauges; 4: hydrography; 5: Complex of clastic and alluvial deposits (Pliocene-Quaternary); 6: Travertine Complex (Quaternary); 7: Volcanic Complex (Pliocene p.p.-Quaternary); 8: Marly-arenaceous Flysch complex (Miocene-Pliocene p.p.); 9: Marly-calcarenitic complex (Jurassic p.p.-Miocene p.p.); 10: Complex of carbonate shelf (Jurassic p.p.-Lower Miocene); 11: Complex of pelagic deposits (Jurassic p.p.-Oligocene))(from Tiber Basin Authority and Boni et al. 1986, modified)

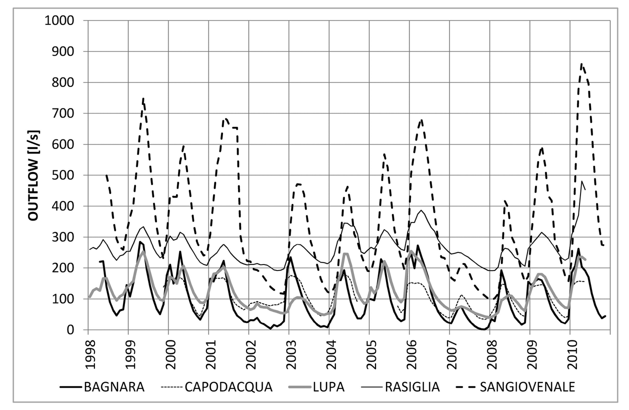


Fig. 2. Hydrographs of the springs Bagnara, Capodacqua, Lupa, Rasiglia and Sangiovenale (ARPA Umbria)

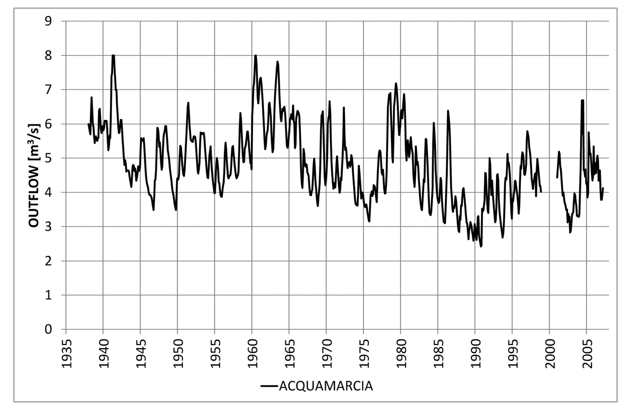


Fig. 3. Hydrographs of the Acquamarcia spring (ACEA, 2001)

Outflow model and analysis procedure

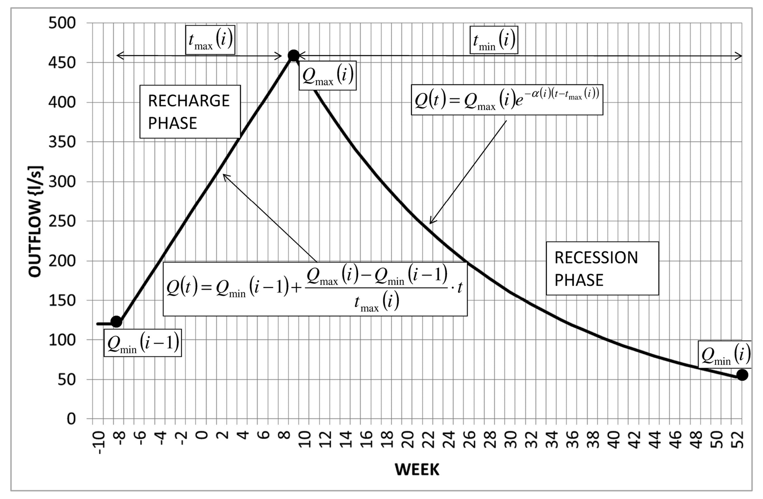


Figure 4. Ideal hydrograph simulating the annual outflow of the studied springs. Time is expressed in weeks

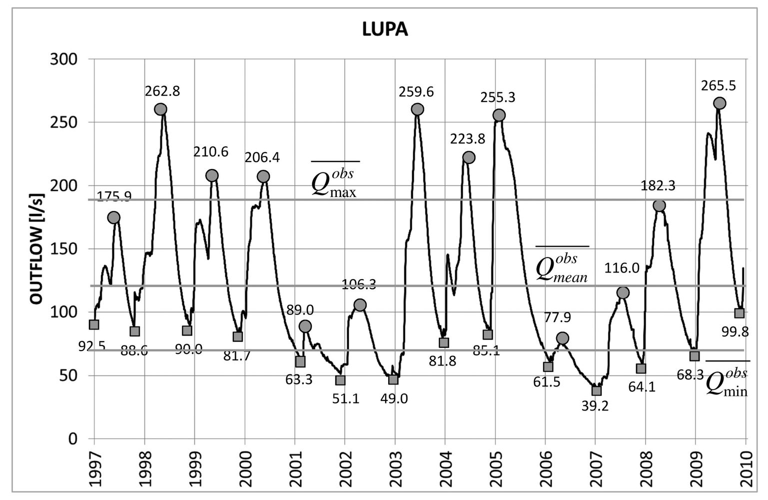


Figure 5 - Example of outflow parameters' "pick-up" performed for the Lupa spring

Step 1. Computation of the linear correlation coefficient between the observed outflow parameters

Step 2. Computation of the SPI_n at local and basin scale. Relations with outflow parameter

Step 3. Assessment of the variability in time of the spring parameters.

Step 4. Validation of the generation method.

Step 5. GENERATION OF SYNTHETIC TIME SERIES.

Step 1 - Computation of the linear correlation coefficient between the observed outflow parameters

Scope: seeking whether a relation among the long term average outflow parameters exists and, in case, if such a relation is similar for all the springs

- $Q^{obs}_{mean}(i)$ strongly correlated with $Q^{obs}_{max}(i)$ and $Q^{obs}_{min}(i)$
- No clear correlations between the outflow parameters and $t^{obs}_{min}(i)$ and $t^{obs}_{max}(i)$

LUPA	$Q^{obs}_{max}(i)$	$Q^{obs}_{min}(i)$	$t^{obs}_{max}(i)$	$t^{obs}_{min}(i)$	$Q^{obs}_{mean}(i)$
$Q^{obs}_{max}(i)$	1	0.78	0.16	-0.54	0.97
$Q^{obs}_{min}(i)$	-	1	0.53	-0.33	0.87
$t^{obs}_{max}(i)$	-	-	1	0.10	0.22
$t^{obs}_{min}(i)$	-	-	-	1	-0.53
$Q^{obs}_{mean}(i)$	-	-	-	-	1

Table 2. Linear correlation coefficient R between the observed outflow parameters $Q^{obs}_{max}(i)$, $Q^{obs}_{min}(i)$, $t^{obs}_{max}(i)$, $t^{obs}_{min}(i)$ and $Q^{obs}_{mean}(i)$ computed for the Lupa spring

SPRING	$\overline{Q_{mean}}/\overline{Q_{min}}$	$R\left(Q^{obs}_{max}(i), Q^{obs}_{min}(i)\right)$	$\overline{Q_{max}}/\overline{Q_{min}}$	$R\left(Q^{obs}_{max}(i), Q^{obs}_{mean}(i)\right)$	$\overline{Q_{mean}}/\overline{Q_{min}}$	$R\left(Q^{obs}_{mean}(i), Q^{obs}_{min}(i)\right)$
BAGNARA	11.96	0.70	2.40	0.91	4.97	0.71
CAPODACQUA	3.15	0.07	1.56	0.86	2.02	0.49
LUPA	2.66	0.78	1.52	0.98	1.76	0.87
RASIGLIA	1.42	0.91	1.23	0.99	1.15	0.89
SANGIOVENALE	3.31	0.82	1.64	0.98	2.01	0.90
ACQUAMARCIA	1.33	0.85	1.16	0.95	1.15	0.94

Table 1. Values of the ratios $\overline{Q_{mean}}/\overline{Q_{min}}$, $\overline{Q_{max}}/\overline{Q_{min}}$ and $\overline{Q_{mean}}/\overline{Q_{min}}$ and related correlation coefficients R

Step 2 - Computation of the Standardized Precipitation Index at local and basin scale. Relations with outflow parameters

Scope: 1. assessing the precipitation input at local and basin scale. 2. assessing the relations with outflow parameters

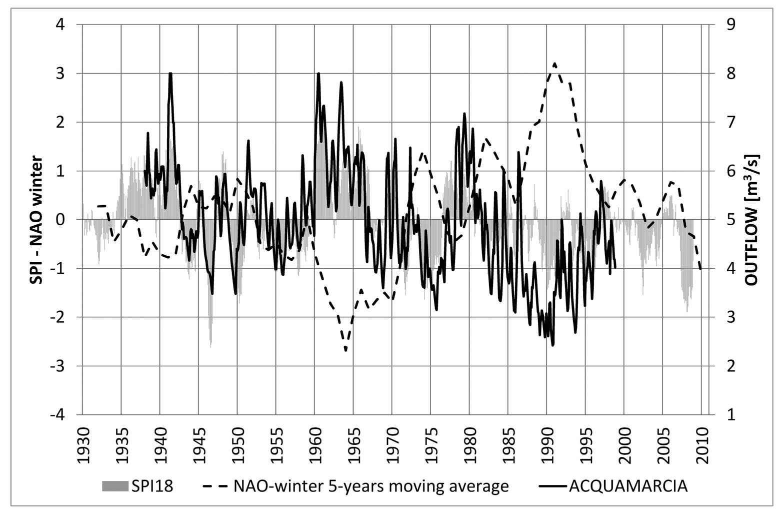


Figure 6. Time evolution of the SPI18 computed at the basin scale (grey bars), monthly Acquamarcia outflow (solid line, secondary y-axis) and monthly winter NAO 5-years moving average /dashed line, main y-axis).

Computation of the SPI for different aggregation time n

Computation of the correlation coefficient between SPI^{basin}_n for each month k and each year i and of the correlation coefficient with the outflow parameters $Q_{max}(i)$, $Q_{mean}(i)$, $Q_{min}(i)$, and $t_{max}(i)$,

PARAMETER	SPI
$Q_{max}(i)$	SPI9_MAY (i)
$Q_{mean}(i)$	SPI12_NOV (i)
$Q_{min}(i)$	SPI12_NOV (i)
$t_{max}(i)$	SPI_6_MAY (i)

Table 3. Correspondences SPI^{basin}_n - outflow parameters used for generating the synthetic time series

Algorithm of generation of synthetic time series

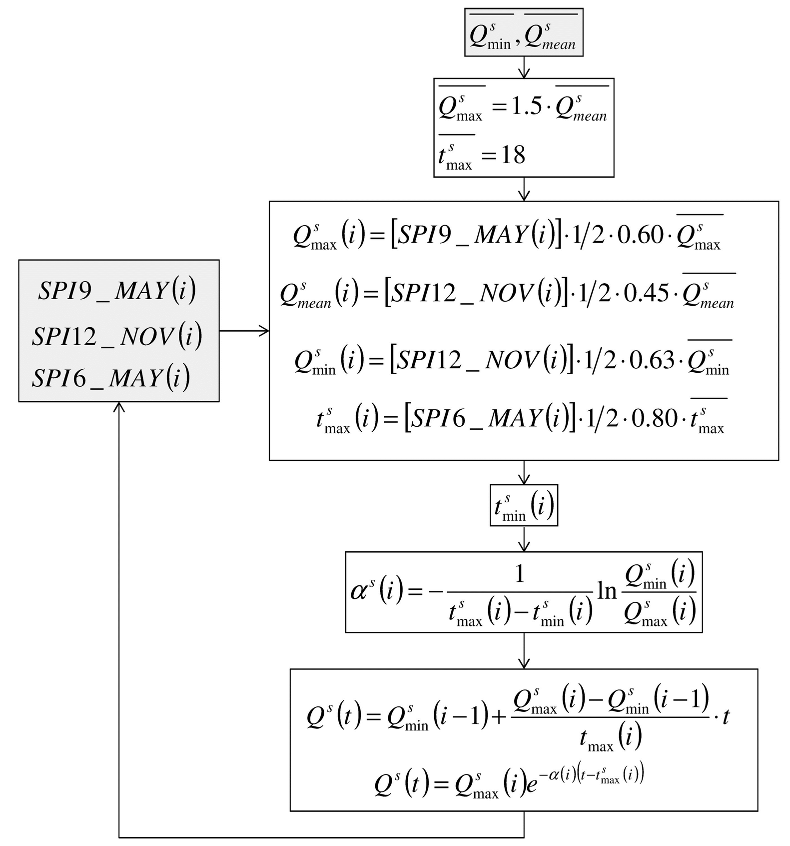


Figure 8. Flow chart of the algorithm developed for generating synthetic hydrograph for the generic spring " for which only long term mean and minimum outflow and are known.

Step 3 - Assessment of the variability in time of the spring parameters

Scope: assessing the variability in time of the outflow parameters in relation to the SPI variability

Computation of the regression line of the time series $\left(SPI^{basin}_n(i,k), P(i)\right)$

Computation of $Q^s_{max}(i)$, $Q^s_{min}(i)$, $Q^s_{mean}(i)$, $t^s_{max}(i)$ as a function of $SPI^{basin}_n(i,k)$

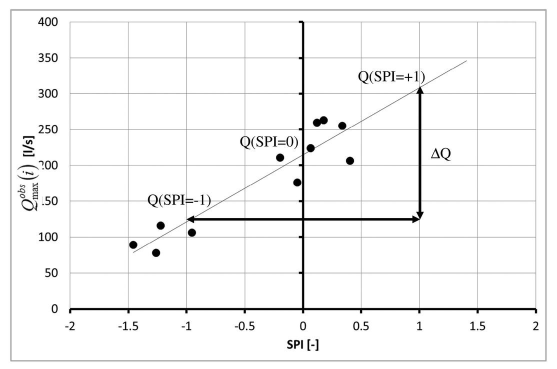


Figure 7. Graphical representation of the procedure adopted to compute the variability of the generic P parameter with respect to the related SPI

Step 4 - Validation of the generation method

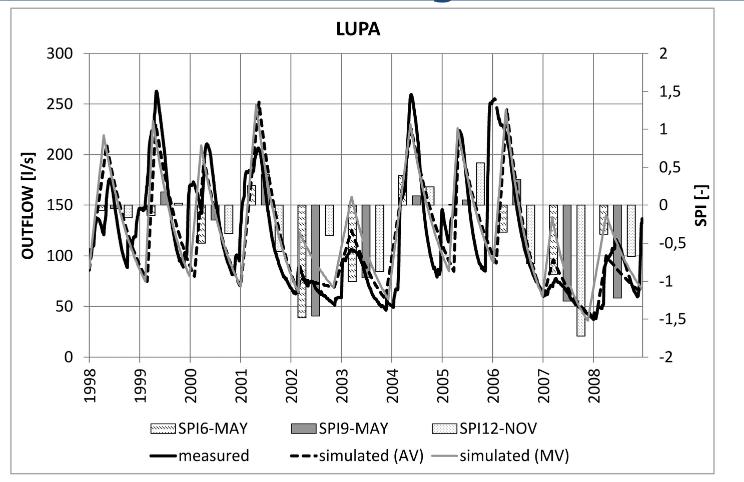


Figure 9. Observed hydrograph (dark solid line), simulated hydrograph compute considering the actual variability of the outflow parameters (solid grey line), simulated hydrograph computed considering the mean variability of the outflow parameters (dashed dark line), SPI6-MAY (horizontal dashed bars), SPI9-MAY (grey bars), SPI12-NOV (white bars)

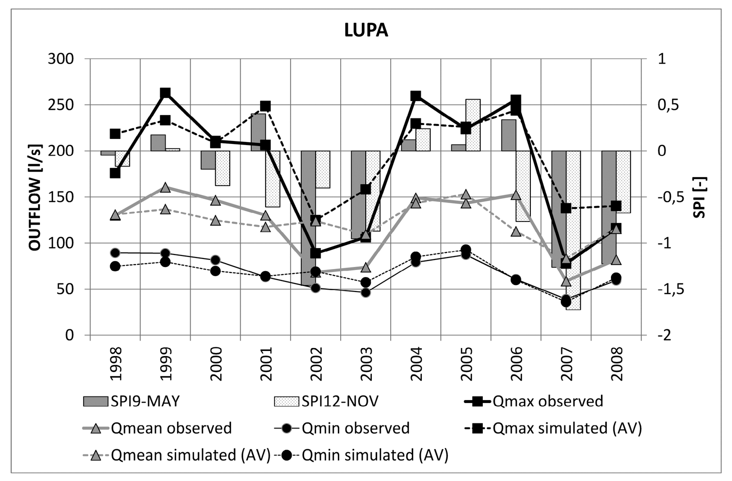


Figure 10. Comparison between observed and computed outflow parameters for Lupa spring. The synthetic outflow parameters have been computed considering the local variability. Dark grey and light grey bars indicate SPI9-MAY and SPI12-NOV, respectively

Step 5 - Generation of synthetic time series

Scope: simulation of the Argentina spring. $\overline{Q_{mean}}$ =657 l/s; $\overline{Q_{min}}$ = 470 l/s

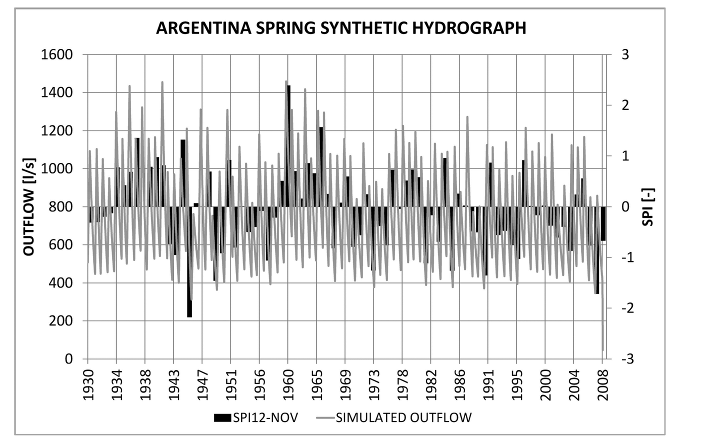


Figure 11. Synthetic hydrograph generated for the Argentina spring (grey line) and SPI12-NOV (dark bars)

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