Regional Estimation of Flow Duration Curves With Some Consideration on Hydropower production

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ABSTRACT

Flow duration curves (FDC) are a powerful tool to represent water availability and variability in a river, and are used for multiple purposes, like for instance reservoir design and river restoration studies.

The presence of existing reservoirs and hydropower plants affects the FDCs and must be taken into account in both local and regional analyses. The procedure adopted here to estimate FDCs operates in affected basins without requiring the reconstruction of the "naturalized" time series, but works only on the L-moments of the FDC, with the purpose to directly reconstruct a "naturalized" FDC. In addition, for a number of basins, more detailed information about the volume of water used by the hydropower plants can be derived, by mean of a reverse procedure, from the available energy production data.

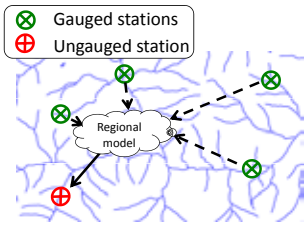
The proposed procedure is systematically extended to all the gauged basins located in Northwestern Italy, which is an area characterized by the presence of a large number of dams. For each basin the annual average FDC is computed, its L-moments are calculated and corrected using a simplified model that takes into account the effect of upstream reservoirs and power plants. Then, we regionalize each corrected L-moment using multiple regressions techniques, allowing one to reconstruct the L-moments at any ungauged basin.

Finally, the "naturalized" FDC is reconstructed at the ungauged site on the basis of the predicted L-moments. The regionalized FDCs can be coupled, where enough information are available, with hydropower production data to get an independent and more detailed estimation of the mean annual flow at the water infrastructure sections.

INTRODUCTION

Flow duration curves (FDC) are the tool usually adopted to represent water availability and variability for hydropower purposes.

FDC are usually determined in ungauged basins by means of regional statistical analysis. The procedure adopted here does not require the definition a priori of an analytics form of the FDC, but works only on the L-moments, that are smoothly varying in the descriptor space.



$$Q(F) = \mu \cdot X(F)$$

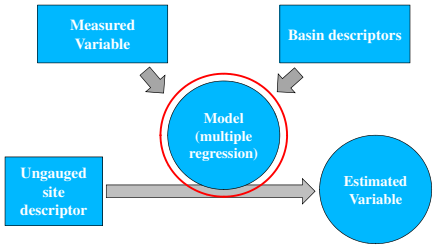
ADIMENSIONAL FLOW DURATION CURVE

SCALE FACTOR

In the present work we estimated and regionalized the scale factor mu and the L-moments of the adimensional FDC. Once the regression model for each L-moment is built, th regional FDC can be reconstructed at ungauged sites in a "spatially smooth" fashion.

MODEL DEFINITION

Statistical regionalization through morpho-climatic basin-scale descriptors



Variable to be regionalized

Usually the distribution is defined a priori, and the parameter of the chosen distribution are regionalized

Distribution-free statistics

- **L-moments regionalization**
- **A posteriori reconstruction of frequency distribution**

Case study

123 gauging station located in North-Western Italy.

For each one of these basins the annual average FDC and the daily runoff L-moments (until the third order) where computed. L-moments were corrected taking into account reservoir and power plants.

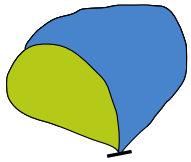
Weighted multiple regression

Regional Analysis →

Building of relations between the L-moments of the FDCs to several geomorphoclimatic parameters (more than 100) of the basins upstream the gauging stations

Congruence of the mean

$$Q_3 = Q_1 + Q_2 = q_1 \cdot A_1 + q_2 \cdot A_2$$



To obtain high-resolution spatial estimates, the method has been designed to keep the estimates of mean annual runoff (i.e. L1) congruent in the confluences. This property is obtained considering only raster-summable geomorphoclimatic descriptors (24 over 100).

Descriptor M_i must respects the following condition:

$$M_{1,3} = \frac{A_1 M_{1,1} + A_2 M_{1,2}}{A_1 + A_2}$$

REGRESSION MODELS

- **MEAN ANNUAL RUNOFF**

Runoff regime parameter; Barycenter x-coordinate; Basin mean elevation; Mean annual precipitation

$$X = fourier_{C1} + fourier_{B2} + x_B + h_m + MAP$$

- **L-CV**

Barycenter Y-coordinate; Exponent IDF curve; Soil Curve Number; Mean L-CV of 12h rainfall

$$X = y_B + IDF_a + CN_1 + LCV_{12h}$$

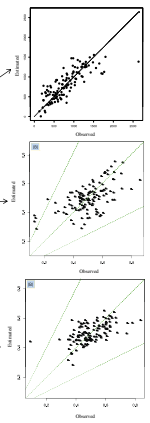
- **L-CA**

Mean L-CV of 3h rainfall

$$X = clc_2 + MAP + CN_{3\text{-}std} + LCV_{3h}$$

Class 2 CORINE Land Cover; Mean annual precipitation; Standard deviation of Soil Curve Number

Observed vs Estimated

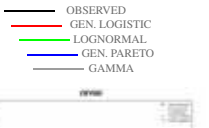


To choose the best relations we consider high coefficients of determination R^2. Models are tested for multicollinearity (VIF) and significance (Student t test).

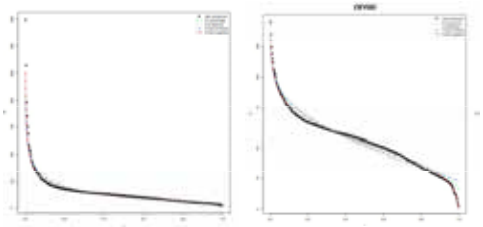
CHOICE OF THE DISTRIBUTION

Identification of reliable analytical curves through post-regionalization model selection. We chose between 4 different PDF. The distribution parameters are calculated by means of the L-moments of the 123 gauging stations taken into consideration [*Hosking and Wallis, 1997*].

The fitting to the observed values is evaluated by means of qualitative (graphical) and quantitative (RMSE) methods, both in logarithmic and linear scale.



Cervo at Quinto Vercellese



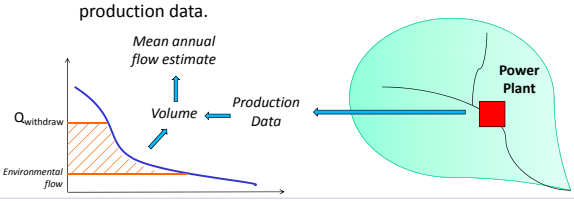
Also considering the distribution boundaries, we decide to choose the **GENERELAZED LOGISTIC DISTRIBUTION**

Finally, the FDC can be reconstructed at the ungauged site on the basis of the predicted L-moments and of the distribution choosen.

INFORMATION FROM HYDROPOWER DATA

At water infrastructure sections more detailed information about the volume of water used by the hydropower plants can be derived, by means of reverse procedure, from the available and reliable energy production data.

Where we have a hydropower plant we can made a local correction of the regional FDC on the basis of the backward reconstruction of the hydrological information from the energy production data.



RESULTS AND FINAL REMARKS

- Subjective choices (like distribution selection) are made only at the end of the regionalization process.
- Effects of powerplants and reservoirs accounted through aproximate corrections of L-moments.
- Possibility to reconstruct missing hydrological information from hydropower production data.