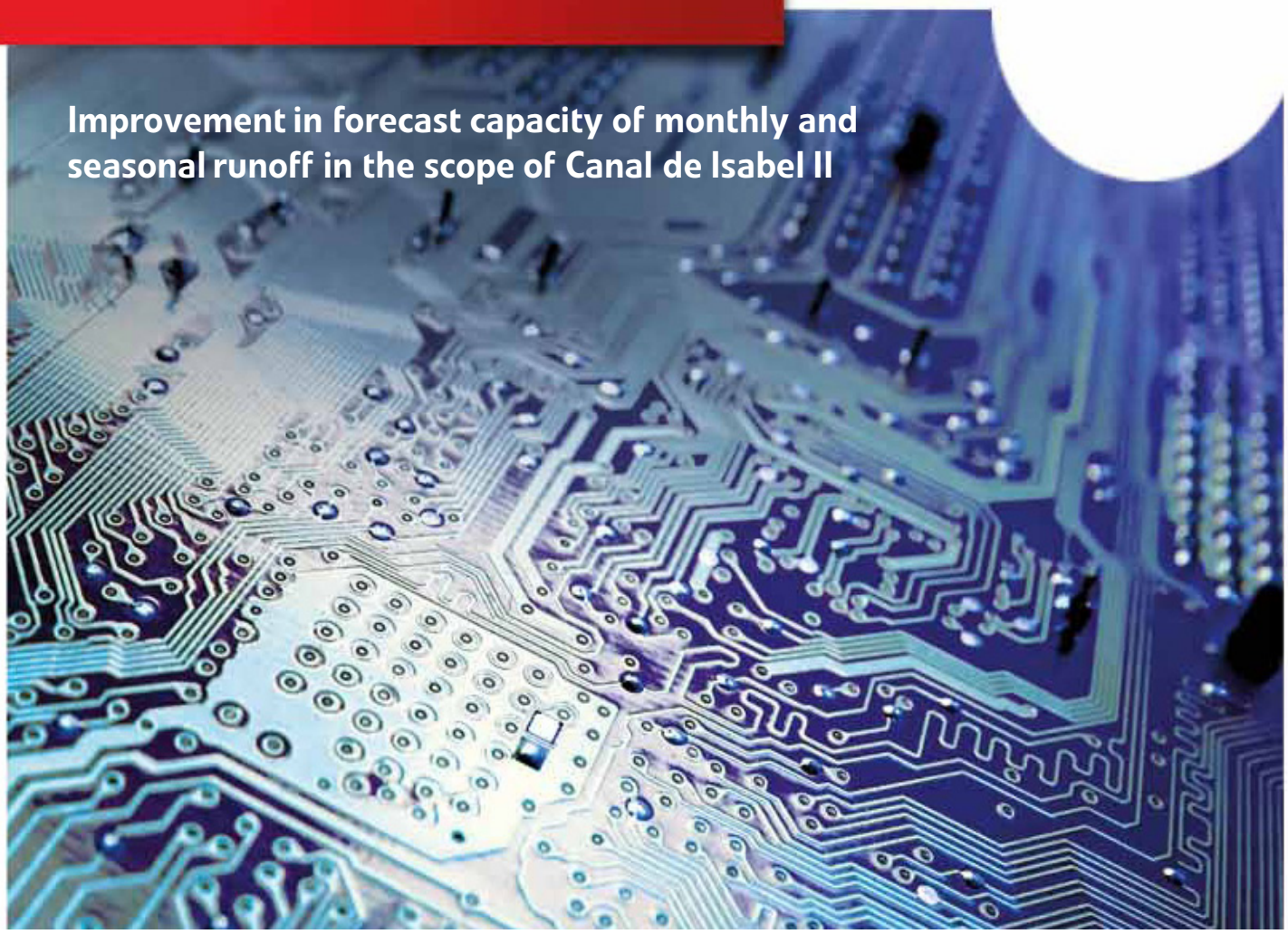
Canal de Isabel II

BOOKLETS

Research + Development & Innovation

17

Improvement in forecast capacity of monthly and seasonal runoff in the scope of Canal de Isabel II



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Introduction

Canal de Isabel II's Research, Development & Innovation Booklets form part of the company's Knowledge Management Strategy and of the development involved in the Research, Development and Innovation Plan.

These Booklets represent an element for diffusion of projects and initiatives that are developed and sponsored by Canal de Isabel II for innovation in those areas related with water service in the urban environment.

A series of different problems that have been undertaken in each project are put forward in the Booklets, along with the results that have been obtained. The intention behind their diffusion by means of these publications is to share the experiences and knowledge that has been acquired with the entire water services sector, with the scientific community and with all those working on investigation and innovation tasks. What is aimed with the publication of these Booklets is to contribute to improvement and efficiency in water management and, consequently, in the quality of service that is provided to the citizens.

The R&D&I booklets published to date are as shown below by their titles in the following table.

Table a. Titles published in the collection

Collection Number	Research, Development and Innovation Booklets published
1	Transferences of Water Rights between Urban and Agrarian Demands. The case of the Community of Madrid
2	Identification of Hydrometeorological Runs and Tendencies within the scope of the Canal de Isabel II system
3	Contribution of Canal de Isabel II to the International Demand Management Project (IDMF)
4	Micro-components and Explanatory Factors on Domestic Water Consumption in the Comunidad de Madrid
5	Virtual Water and Hydrological footprint in the Comunidad de Madrid
6	Study on the saving potential of water for residential uses in the Comunidad de Madrid
7	Potentials of efficiency in using dishwashers in the Comunidad de Madrid
8	Accuracy in the measurement of individual water consumption in the Madrid Region
9	Research project to define and assess the applicability of a Bioassay Test to determine the toxicity of water using Zebra Fish embryos
10	Water Use Efficiency in Gardening in the Region of Comunidad de Madrid
11	Remote sensing techniques and geographical information systems for assessing water demand for outdoor uses in the Comunidad de Madrid
12	Cyanotoxin Dynamics Study in two of the Canal de Isabel II's supply reservoirs in the autonomous region of Comunidad de Madrid
13	Development of a validation, estimation and prediction of hourly consumption by sector, for the distribution network of Canal de Isabel II
14	Monitoring urban consolidation evolution in the Autonomous Region of Madrid using remote sensing techniques
15	Experiences for phosphorous recovery from wastewater as struvite in Canal de Isabel II
16	Integration of weather forecasting in the management modules supply system of Canal de Isabel II, via daily runoff models

Project Outline

Project title	Improvement in forecast capacity of monthly and seasonal runoff in the scope of Canal de Isabel II .
Research line	Guarantee strategic continuity of service
Canal de Isabel II areas involved	R+D+i Deputy Direction
External participation	Ecología y Tecnología del Medio Ambiente, S.A. (Grupo GETINSA)
Aim and justification of the project	Develop statistical tools to forecast monthly or quarterly runoff, which incorporate runoff from immediate past as input data, and rainfall information for said period insofar as it is available.
State of the art contribution	An original statistical formula has been tested on the relation between runoff for a period (dependent variable) and synchronic rainfall, and runoff for the previous period (independent variables). A methodology has been designed and applied to include information on future rainfalls based on a NAO index prediction in the runoff forecast.
Project development summary and milestones	Make known the result of assessing several statistical formulas to represent the ratios between monthly and seasonal hydrometeorological variables. A revision was made of the possibilities that the current weather forecast offers, for monthly, or seasonal rainfall forecasting.
Obtained results summary	Statistical forecast models for covering one month or a season, for 14 series of runoff to reservoirs or sets of reservoirs.
Research lines open for continuing the work	• Incorporation of information related to the amount of water accumulated from snowfall to forecast runoff, for winter and spring months. Research includes possible sources for said information (e.g. Remote sensing). • Incorporation of seasonal rainfall forecasts as developed and improving their capacity.

Executive Summary

What will be the amount of the runoff they will receive, next month, this or that reservoir? The research presented in this R+D+i booklet explores the possibilities of giving a reliable more or less accurate answer to those questions in relation to the reservoirs managed by Canal de Isabel II.

The historic monthly runoff values enable appreciation of the range of expectable runoff per month. Moreover, it enables adjustment of empirical probability distribution function where probability values can be associated with expectable runoff values. For example, in the period 1940-41 to 2003-04 (64 hydrological years), only 8 times was the runoff to El Vado reservoir under 6.5 million cubic metres. With this statistic we can accept the probability of equalling or surpassing a runoff of 6.5 million cubic metres to El Vado reservoir, in January, is 1-8/64 = 7/8, i.e. 87.5%. Can the accuracy of the runoff estimations obtained from the empirical probability distribution be improved?

During previous research set forth in R+D+i Booklet N°2, *Identification of Hydrometeorological Runs and Tendencies within the scope of the Canal de Isabel II system*, it was demonstrated the existence of persistence ratios among consecutive monthly or quarterly runoff, which was imputed to the hydrological inertia of the river basins. Thus, if a December is wetter or drier than usual the following January runoff will tend to be greater or fewer than normal. Thus, if we know the December runoff and it is considerably higher than usual, we can expect a January runoff over 6.5 million cubic metres, likely exceeding 87.5%, attributed to a generic January via distribution of historical probability. In this research, methods were established enabling quantification of probabilities conditioned to the previous month runoff.

Furthermore, the runoff forecast models proposed, explicitly include the variable **"rainfall"**, so more accurate runoff forecasts are obtained when starting with a supposition regarding rainfall for the forecasted period.

In conclusion:

1) Runoff value in, for example, January runoff for El Vado reservoir is considered a random variable and initially, its distribution probability can be estimated from the sample created by its historical series.
2) Said variable is conditioned by others like the previous month's runoff or rainfall of the current month (initially unknown).
3) Research carried out develops and tests an original formula to express probability distribution of a month's runoff, conditioned to the previous month's runoff value, and an accumulated rainfall value of the problem month.

The proposed formula has two degrees of freedom and is based on the gamma distribution model. Runoff models, conditioned per month and per each of the 14 series of runoff to Canal de Isabel II's reservoirs, were adjusted with this. Adjustments were made for hydrological years 1940-41 to 2003-04. The monthly value recorded on the Madrid-Retiro pluviommeter is used as the rainfall data.

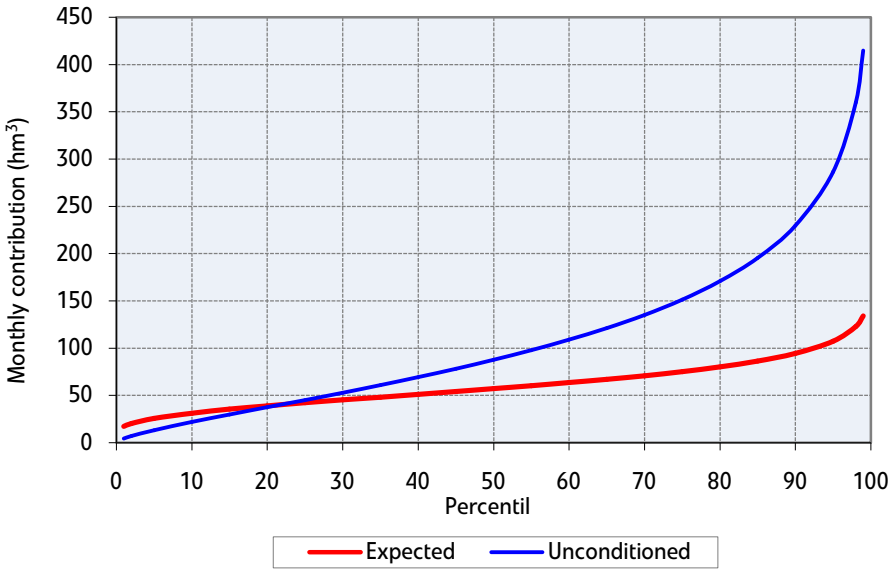
Knowing the previous month's runoff and supposedly the rainfall of the problem period (month or quarter), the model provides a probability distribution for the problem period runoff, which generally presents less uncertainty (lower variation coefficient) than distribution initially.

As soon as the monthly runoff is known, the model can be applied to forecast (in probability terms), the following month's runoff, except where rainfall is unknown for that month. "**Case 1**" is application of the model with a supposed rainfall value for the problem month. Application of "**Case 1**" enables assessment of hypothetical scenarios of future rainfall (scenarios type: "What happens if...?"). However, it does not provide a forecast as such since it lacks reliable information on future rainfall value.

To obtain a runoff forecast regardless of the synchronic rainfall value, a model called "Case 2" was developed integrating the conditioned runoff probabilities for rainfall values from the historical series. Therefore, probability distribution resulting from "Case 2" does not include information on synchronic rainfall, but on the previous month's runoff.

Figure a. El Vado reservoir

Distribution of the January aggregate runoff for the December aggregate runoff of 60 hm^3 and January rainfall of 40%



Both applications of the models "Case 1" and "Case 2" were implemented in an Excel based application and the usefulness of the forecasts provided are being assessed insofar as they can be validated with actual data.

Furthermore, a good seasonal rainfall forecast (1 month, 1 quarter) would substantially improve estimations of future runoff; thus current possibilities for this forecast type, for the region affecting Canal de Isabel II was revised.

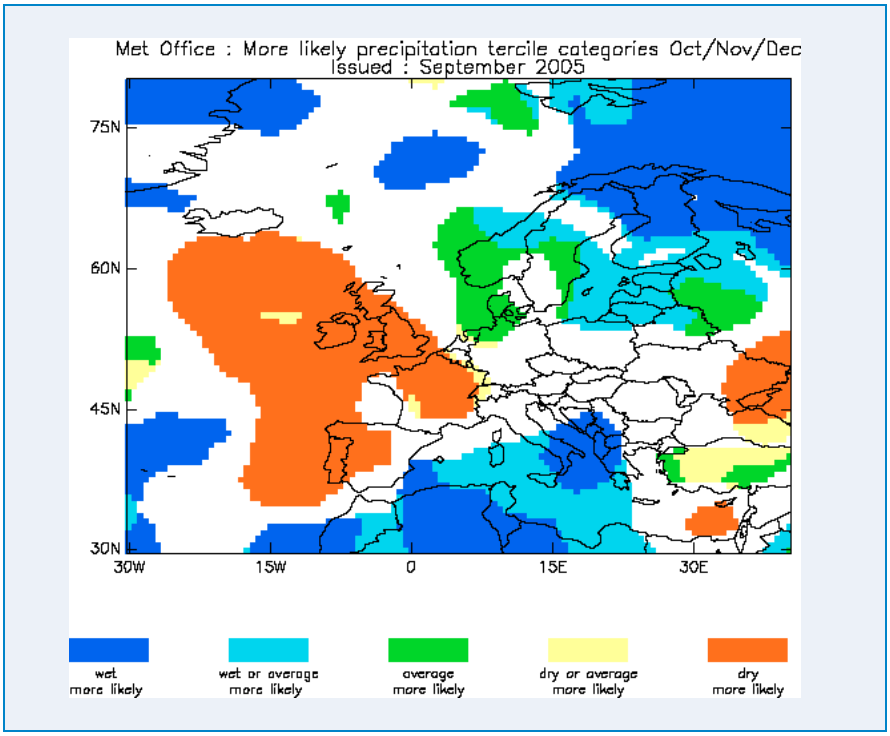
In particular, the regional season rainfall forecasts published by the UK Met Office were assessed, likewise possible relations between seasonal rainfall and two regional climate phenomena: ENSO[1] (El Niño Southern Oscillation) and NAO[2] (North Atlantic Oscillation) were researched.

[1]ENSO: El Niño Southern Oscillation is a phenomenon explained by the earth's rotation, and consequently displacement of the tides in the northern and southern hemispheres, always within the intertropical area. It is erratically cyclical (cycles between 3 and 8 years). It is a change in the movement patterns of the sea currents in intertropical area, consequently causing a superimposition of warm waters from the northern hemisphere immediately north of the equator over the very cold emersion waters characterized by the Humboldt Current. This situation causes damage on a zonal level (intertropical zone); due to intense rains, mainly affecting South American on both the Atlantic and Pacific coasts.

[2] NAO: North Atlantic Oscillation, refers to the oscillation in the distribution of the atmospheric mass between the Arctic and the sub-tropical Atlantic in the Northern hemisphere. Its positive phase is characterize by abnormally low presses in the Arctic in contrast to the abnormally high pressures in mid-Atlantic latitudes, causing an N-S gradient of higher than normal atmospheric pressure, at the same time as a greater influence of the high pressures in the mid-latitudes. NAOI is the winter NAO status.

Regarding the NAO oscillation, it has been verified it is clearly related to winter rainfall in the Iberian Peninsula centre. Given the existence of probability forecasts for several indicators of this oscillation (like those published by Benfield Hazard Research Centre, of London University), the possibilities of including them in the winter runoff forecast models developed have been explored. "Case 3" of the model resulted from this application, which includes winter rainfall probability forecasts based on the forecast of a NAO index.

Figure b. Graphic example of regional rainfall prediction with quarterly scope prepared by the Met Office



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