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Use of bias correction techniques to improve seasonal forecasts for reservoirs — A case-study in northwestern Mediterranean

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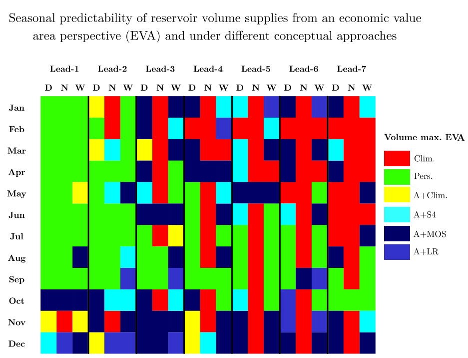
HIGHLIGHTS

- Bias correction of seasonal forecasts at a river basin scale
- Application of MOS-analog, mean bias and linear regression bias adjustments
- Bias correction effect on the seasonal predictability of volume anomalies
- Analysis of the potential for end-users through economic value curves

GRAPHICAL ABSTRACT



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ABSTRACT

In this paper, we have compared different bias correction methodologies to assess whether they could be advantageous for improving the performance of a seasonal prediction model for volume anomalies in the Boadella reservoir (northwestern Mediterranean). The bias correction adjustments have been applied on precipitation and temperature from the European Centre for Middle-range Weather Forecasting System 4 (S4). We have used three bias correction strategies: two linear (mean bias correction, BC, and linear regression, LR) and one non-linear (Model Output Statistics analogs, MOS-analog). The results have been compared with climatology and persistence. The volume-anomaly model is a previously computed Multiple Linear Regression that ingests precipitation, temperature and in-flow anomaly data to simulate monthly volume anomalies. The potential utility for end-users has been assessed using economic value curve areas. We have studied the S4 hindcast period 1981–2010 for each month of the year and up to seven months ahead considering an ensemble of 15 members. We have shown that the MOS-analog and LR bias corrections can improve the original S4. The application to volume anomalies points towards the possibility to introduce bias correction methods as a tool to improve water resource seasonal forecasts in an end-user context of climate services. Particularly, the MOS-analog approach gives generally better results than the other approaches in late autumn and early winter.

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1. Introduction

The management of water resources is a complex issue, specially in regions prone to hydrological stress and water scarcity (e.g. Pedro-Monzonís et al., 2015). In such situations, end-users have to carefully plan their actions to choose the best decisions and minimize their potential losses (e.g. Wilhite et al., 2000; Bodner et al., 2015). This process is mainly driven by water resource forecasts (Sene, 2010) and the vulnerability degree of the end-user (Downing et al., 2005; Dow et al., 2007). For this purpose, although near-term meteorological forecasts are the most used (e.g. Habets et al., 2008; Adamowski and Karapataki, 2010; Iglesias et al., 2012), the seasonal forecast horizon holds the largest potential, for having information months ahead can substantially increase the resilience of the forecast users (e.g. Block, 2011; Tall et al., 2012; WMO and GFCS, 2016). However, in the operational time-scales, seasonal forecasting is still limited to the use of climatology, a rather conservative approach to diminish the risk of taking misleading decisions (e.g. Cubillo and Garrote, 2008). In fact, regarding dynamical seasonal forecast systems, they are seldom used by any end-user, a preference that can be explained because the skill of these seasonal forecasts is limited in the extra-tropics and for it is difficult to easily communicate the usefulness of the forecasts (e.g. Rayner et al., 2005; Watkins and Wei, 2008). Therefore, it is important to explore new ways to improve seasonal dynamical forecasts and give new insights in their usefulness to provide end-users with the adequate information to decide the best choice for their water management strategies.

The problem of water scarcity, its management and forecast has been already assessed in current literature (e.g. Sene, 2010; Donkor et al., 2014; Bodner et al., 2015). This issue is specially harsh in the Mediterranean where the water deficits of dry summers are often unresolved in the wet season, leading to recurrent drought situations (Blinda et al., 2007; Cook et al., 2016). Under these events resource planning is critical and has to be performed in a seasonal basis. Moreover, this vulnerability is likely to increase in the future due to the rise of drought frequency linked to climate change (e.g. Brewer et al., 2006; Nicault et al., 2008; Turco and Llasat, 2011; Quintana-Seguí et al., 2011) and the growth of water demands (Iglesias et al., 2007). Consequently, in the Mediterranean areas seasonal forecasting could be a very valuable tool to optimize end-user actions and decisions.

Nowadays, although the existing studies confirm the idea that predictability in the extra-tropics is reduced in comparison to the tropics, this does not mean that it is missing at all (e.g. Stockdale, 2000; Quan et al., 2006; Folland et al., 2012; Doblas-Reyes et al., 2013; Scaife et al., 2014; Marcos et al., 2015). However, in spite of the steady advances, seasonal forecasting has to face many theoretical and practical challenges to become an everyday tool in the extratropical regions. Actually, the raw forecasts from dynamical systems show biases in comparison to the reference datasets. These biases are the consequence of the inherent limitations of the physical models related to parameterizations, equation simplification and uncertainties in the initialisation procedure (Doblas-Reyes et al., 2013). Such uncertainties can be mitigated through the application of linear and non-linear bias correction techniques that are normally based on statistical methods using antecedent series of forecasts and observations (Weigel et al., 2009; Piani et al., 2010; Peng et al., 2014). However the identification of the best techniques it is not straightforward and might depend on the domain and variable considered as well as in the nature of the bias correction technique itself.

In this paper, we want to study the application of three bias correction approaches (two linear and one non-linear) on the seasonal forecast outcome from the S4 (Molteni et al., 2011). The bias corrected variables then will be introduced in a previously developed (Marcos et al., 2017) seasonal volume-anomaly monthly model for the Boadella reservoir, northwestern Mediterranean, to check whether the use of bias correction techniques is able to improve their outcome compared to climatology and persistence. Additionally, our implementation will take advantage of the economic value verification as an opportunity to improve the communication of the results to end-users (Marcos et al., 2017).

This paper is organized as follows: "Material and methods" 2 section is a comprehensive description of the domain and the data used in this study; "Methodology" 2.3 presents the implementation framework of the bias correction methods and the volume-anomaly model; "Results" 3 contains the verification metrics of the bias corrections applied and the volume-anomaly performance comparison; and, finally, the "Conclusions" 4 section summarises the main results obtained.

2. Material and methods

2.1. Domain: the Muga Basin and the Boadella reservoir

The Muga River basin is located in the northeastern part of the Iberian Peninsula. It covers a Catalan region delimited to the north by the Pyrenees, and the Mediterranean to the east (Fig. 1). Although its surface is relatively small, about 854 km^2, there are high contrasts between the mountainous region, with altitudes around 1100 m (summits about 1400 m) and the lower sedimentary plains. The river Muga, which gives the basin's name, is 64 km long and in its upper flow is regulated by the Boadella reservoir, which collects water from a sub-basin of approximately 182 km^2 (Fig. 1). The maximum length of the reservoir is 8.5 km and it has a depth of 54 m. It occupies an area of 364 ha, and its capacity is of 61 hm^3 (Pavón, 2001a,b; Colomer et al., 2004). It accomplishes four goals: *a*) flood lamination *b*) irrigation *c*) urban water supply and *d*) electricity production.

The mountainous area is mainly covered with forests whereas the lower heights are devoted to agriculture. Main urban areas lie in the lower stream. Its climograph shows that summer is the hottest and driest season (Fig. 2). On the contrary, the wettest season is autumn, with a secondary maximum in late spring (April–May). The coldest season is winter, whereas spring and autumn are milder and show some inertia from the precedent seasons. Temperatures along the year are always positive and tend to be cool in winter (max. ~13 °C; min. ~3 °C), mild in spring–autumn(max. ~17 °C; min. ~10 °C) and hot in summer (max. ~27 °C; min. ~16 °C).

2.2. Datasets

In this paper, we use E-OBS v8.0, the European Observational dataset (Haylock et al., 2008), as our reference dataset for atmospheric variables. This is an open dataset covering the European domain at a daily basis, with a resolution of 0.25° × 0.25° from 1950 to nowadays. On the other hand, the seasonal forecasts are given by the European Centre for Medium-range Weather Forecasting System 4 (S4; Molteni et al., 2011), a leading operational seasonal prediction system based on a fully coupled general circulation model that provides operational multi-variable seasonal predictions at 0.75° horizontal resolution. To evaluate the S4 prediction quality and to perform the bias corrections, we also use a set of retrospective forecasts (re-forecasts or hindcasts) emulating real predictions for a 30-year period (1981–2010) with a 15-member ensemble and 7 months forecast horizon for predictions. Each member of the 15-member ensemble comes from the same model (the ECMWF System-4) and is independent of each other. They are the result of running the ECMWF System-4 with slight changes in the initial conditions. Their resolutions are the same and, also, their grid-points (for further details please see Molteni et al., 2011). The S4 original grid (0.75° × 0.75°) has been bi-linearly interpolated to match the 0.25° × 0.25° E-OBS grid and, hence, ease the process of verification and analog search. We have used bilinear interpolation because it is the most straightforward strategy to increase the grid's