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# Reservoir thermal impact captured by satellite images

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## ABSTRACT

We used Landsat 8 thermal images to study the longitudinal patterns of surface water temperature in the Mequinenza reservoir, Spain, in 2016. We also estimated its thermal impact on the river by comparing upstream and downstream temperatures.

## 1 INTRODUCTION

Field monitoring of freshwater bodies is costly and may be difficult due to accessibility or logistic reasons. In addition, direct measurements have limited capacity to capture fine spatial gradients over large areas.

Free satellite data such as those from the Landsat mission enable the observation of spatial patterns at low cost. The potential of satellite data for monitoring the reservoir thermal status was first pointed out in [1]. Here, we used Landsat -8 imagery to measure surface temperature gradients over the long Mequinenza reservoir throughout an annual cycle. The results provided new insight of the reservoir thermal impact, virtually unattainable from field campaigns.

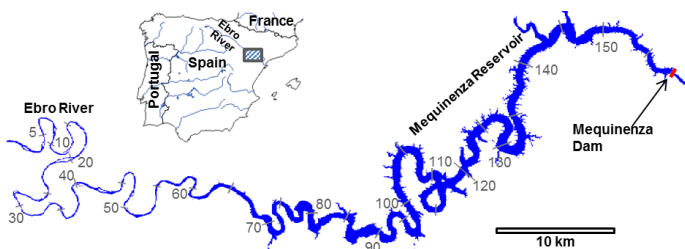


Figure 1. Location of the Mequinenza reservoir.

## 2 STUDY AREA

The study area encompasses the Mequinenza reservoir in the Ebro River, Spain (Fig. 1). Located in the transition between the medium and the lower Ebro, the Mequinenza reservoir is approximately 100 km long, with an average width and depth of 600 m and 20 m, respectively [2]. The main purposes

of the reservoir are flood control and hydroelectric production. During normal operation, water is released through the dam 5 m above the reservoir bed. The reservoir stratifies thermally in the spring (March-April). The stratification is maintained during the summer and autumn, until the ambient low temperatures and high river inflows induce vertical mixing [2].

## 3 SATELLITE DATA AND METHODOLOGY

We used nine cloud-free images of the study area acquired in 2016 by the Landsat 8 Thermal Infrared Sensor (TIRS) band 10 (10.60-11.19  $\mu\text{m}$ ). These data were acquired at 100 m of spatial resolution and distributed at a 30 m resolution after resampling by cubic convolution.

The TIRS band 10 data were calibrated to top-of-atmosphere TOA radiance using the scaling factors indicated in the metadata. TOA radiance was then corrected for atmospheric effects using the Atmospheric Correction Parameter Calculator [3]. The water leaving radiance was converted to surface temperature using Planck's law.

Pure water pixels were identified by using the Modified Normalised Difference Water Index [4] with a threshold of 0.05 and a water mask was produced. Unfortunately, the cubic convolution resampling causes the mixing of radiances from neighbouring water and bank pixels. Only those water pixels centred in a 210 m x 210 m pure water area are confidently free of convolution induced mixing, and therefore reliable for surface temperature retrieval. Such pixels were selected by the application of a digital image processing technique named morphological erosion, using a square structural element of 7 x 7 pixels.

The presented technique limits the retrieval of surface temperature to reaches wider than 210 m. A sharpening algorithm for temperature mapping in narrower reaches is currently in preparation.

## 4 RESULTS AND DISCUSSION

Figure 2 shows the long surface temperature profiles in the Mequinenza reservoir obtained from the Landsat-8 images from August to November 2016.

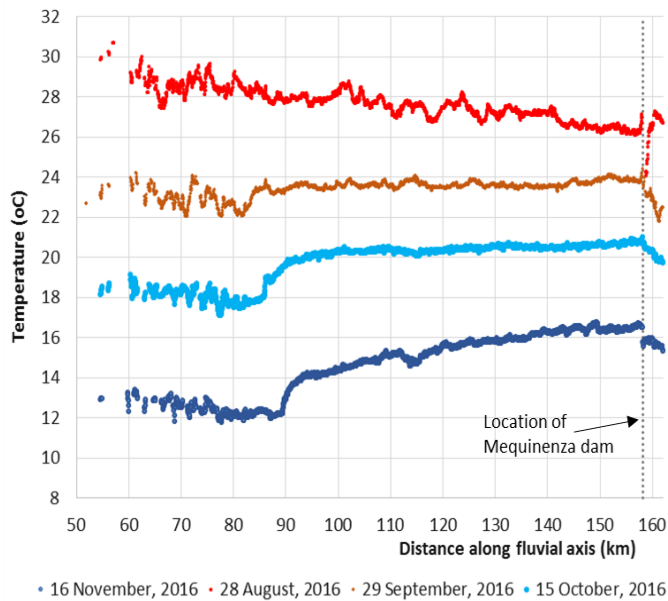


Figure 2. Profiles of water surface temperature in the Mequinenza reservoir retrieved from Landsat-8 images.

The nine thermal profiles revealed negative temperature gradients (i.e. decreasing in the downstream direction) from May to August, and positive ones from September to November, as opposed to what would be expected in temperate rivers. This is a reflection of a common reservoir impact on the natural fluvial thermal regime: the delay of the water cooling in autumn and its warming in spring, due to the large thermal inertia of the impounded volume.

The retrieved temperature gradients provided spatial quantitative insight of the reservoir thermal impact and disclosed relevant information on the stratification status. For instance, the plunge cross section is clearly identified by a sharp temperature increment between km 80 and km 90 from September to November, revealing that the reservoir remained stratified till late in the year. The intensity of the stratification was also quantified from the difference in water surface temperature right upstream and downstream of the dam (km 158).

We estimated the thermal impact of the reservoir as the difference between temperature in the flowing river, upstream of the reservoir, and the first measured temperature downstream of the dam (Fig. 3). From April to the end of September water surface temperature at the dam outlet was up to 2.1 °C cooler than at its tail, since the discharge is abstracted from the hypolimnion cool water. In October and November, instead, water downstream of the reservoir was up to 3.7 °C warmer than upstream.

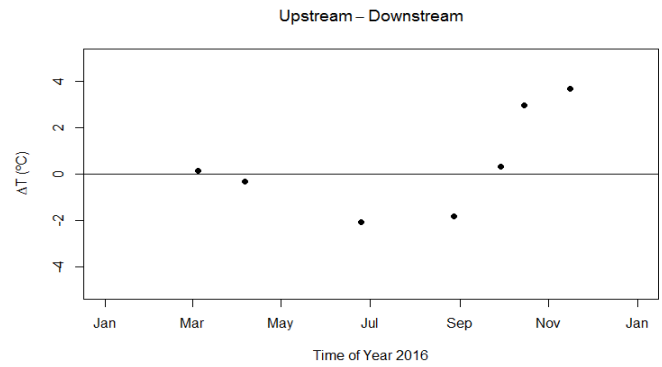


Figure 3. Thermal impact of the Mequinenza reservoir.

## 5 CONCLUSION

The surface temperature profiles derived from the Landsat-8 images provide instantaneous, spatially distributed measurements over the 100 km long study area, which are not attainable through direct sampling. The retrieved profiles offer a quantitative insight on the reservoir thermal stratification, such as the location of the plunge section, and on the thermal impact of the reservoir over the river natural thermal regime.

## 6 ACKNOWLEDGEMENTS

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