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# LakeSST: a satellite-derived water surface temperature data set to study the thermal behaviour of French water bodies

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## ABSTRACT

LakeSST (Lake Skin Surface Temperature) is a data set derived from Landsat thermal images, containing data for 442 French water bodies for 1999-2016. We show an example of application to study the thermal regime of the reservoir of Bimont.

## 1 INTRODUCTION

Satellite images provide a wide spatial and temporal coverage of the Earth's surface that makes them an interesting tool to study long-term and large-scale patterns. Landsat thermal infrared (TIR) images are especially useful to study the surface temperatures of inland water bodies given their relatively high resolution (original resolution of 60-120 m, distributed as 30 m resampled images) and frequent measurement period (16 days). We used TIR images from Landsat 5 and Landsat 7 satellites to produce the LakeSST (Lake Skin Surface Temperature) data set. We show an example of the utilisation of this data set to analyse the long-term thermal behaviour of a French water body.

## 2 THE LAKESST DATA SET

The LakeSST v. 1.2 data set [2] is available at <https://doi.org/10.5281/zenodo.1041746>. It contains data on 442 French water bodies (lakes, reservoirs, ponds, gravel pit lakes, quarry lakes). The skin surface temperatures for 1999-2016 were obtained by applying the algorithm of Jiménez-Muñoz et al. [1] to TIR images measured by the Landsat 5 TM and Landsat 7 ETM+ instruments. We applied several mask layers (clouds, clouds shadows, etc.) to filter out invalid pixels. We filtered out mixed land-water pixels by using a buffer width depending on the native pixel size of TIR images (170 m for Landsat 5, 85 m for Landsat 7).

The data set provides summary statistics for each TIR image with exploitable data for each studied water body. We used the median of the pixel temperatures in an image to estimate the average skin surface temperature, since it is largely insensitive to

outliers and missing data. We selected the data for clear-sky conditions (clearness index  $\geq 0.6$ ) only.

## 3 SKIN TEMPERATURES VS. BULK TEMPERATURES

The temperatures provided by the LakeSST data represent measurements at  $\sim 10\text{-}20\ \mu\text{m}$  below the air water interface. Because of the vertical thermal gradient in the subskin layer and in the surface mixed layer, there is a difference between skin temperature ( $T_{skin}$ ) and bulk temperature (or temperature at the depth  $z$ ,  $T_z$ ):

$$T_{skin} = T_z + \Delta T_c + \Delta T_{w,z} \quad (1)$$

where  $\Delta T_c$  is the cool skin effect and  $\Delta T_{w,z}$  is the warm layer effect at the depth  $z$ , due to the diurnal mixed layer. We used hourly water temperature data at the reservoir of Bimont ( $5^\circ 33' \text{ W}$ ,  $43^\circ 33' \text{ N}$ ) and meteorological data at the nearby station of Aix-en-Provence to investigate the relation of eq. (1).

We estimated the cool skin effect using the model of Fairall et al. [3]. The estimated average cool skin effect was  $-0.46\ ^\circ\text{C}$ , while the first and third quartiles were  $-0.3\ ^\circ\text{C}$  and  $-0.6\ ^\circ\text{C}$ , respectively.

We calculated the warm layer effect at 0.55 m as:

$$\Delta T_{w,0.55m} = T_{0.01m} - T_{0.55m} \quad (2)$$

The average observed  $\Delta T_{w,0.55m}$  was  $0.0\ ^\circ\text{C}$ , being mostly positive during the day (up to  $3\ ^\circ\text{C}$ ) and mostly negative during the night (down to  $-0.7\ ^\circ\text{C}$ ). For wind speeds above  $7\ \text{m/s}$ , the warm layer effect at  $0.55\ \text{m}$  disappeared. Since images were taken at  $10:00\text{--}10:30\ \text{UTC}$ , we calculated the mean  $\Delta T_{w,0.55m}$  at  $10:00\ \text{UTC}$ , that was  $0.07\ ^\circ\text{C}$  (std. error  $0.24\ ^\circ\text{C}$ ).

Then, from eq. (1) and previous results,  $T_{0.55m}$  at the reservoir of Bimont was estimated as:

$$T_{0.55m} = T_{skin} + 0.46 - 0.07 = T_{skin} + 0.39 \quad (3)$$

The RMSE of the surface temperatures corrected with eq. (3) was  $1.2\ ^\circ\text{C}$ .

## 4 THERMAL BEHAVIOR OF THE RESERVOIR OF BIMONT

We show below an example of the application of LakeSST data for the study of the thermal behavior of the reservoir. Satellite-derived temperatures were corrected by applying eq. (3). The annual periodic component of surface temperature was modelled as a sinusoidal function (Fig. 1). Then the temperature series was deseasonalized by removing the annual periodic component (Fig. 2).

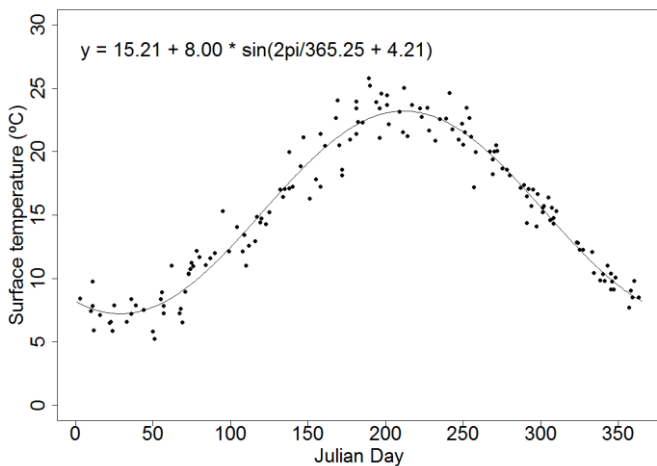


Figure 1. Surface temperature at the reservoir of Bimont as a function of the Julian day.

According to the satellite data, the mean annual surface temperature at Bimont was 15.2 °C, with an average range of 16 °C. Minimum average temperatures were ~7 °C in January-February, and maximum average temperatures were ~23 °C in June-July.

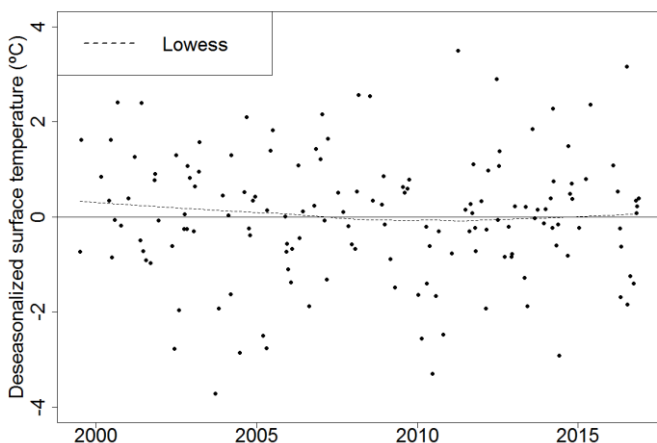


Figure 2. Deseasonalized temperatures at the reservoir of Bimont for 1999-2016 and smoothed Lowess curve.

The reservoir of Bimont, located in the Mediterranean region, was not very sensitive to the effects of climate change. No statistically significant trend was observed in the 18-year-long period covered by the data set. This result parallels recent simulation work [4] which predicted a low warming rate of Bi-

mont's epilimnion waters of 0.009-0.024 °C/yr during the 21<sup>st</sup> century.

Also, because of the noise in the deseasonalized temperature series, longer time series may be necessary to identify trends confidently, especially feeble ones. To reduce the noise, it may help to use more complex corrections of the cool skin and warm layer effects.

## 5 CONCLUSION AND PERSPECTIVES

Remotely-sensed data are indispensable to study the annual and long-term ecological trends over large territories. This is the aim of LakeSST data set, focusing on the thermal behaviour of French inland water bodies. In the near future, the LakeSST data set will be updated and supplemented by data from Landsat 8 (launched in 2013), increasing the volume of available data and its potential to provide a deeper understanding of the thermal trends in lake ecosystems.

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